

NO-A164 789

RADAR TARGET CLASSIFICATION STUDIES - SOFTWARE  
DEVELOPMENT AND DOCUMENTATION(U) OHIO STATE UNIV  
COLUMBUS ELECTROSCIENCE LAB A KAMIS ET AL. SEP 85

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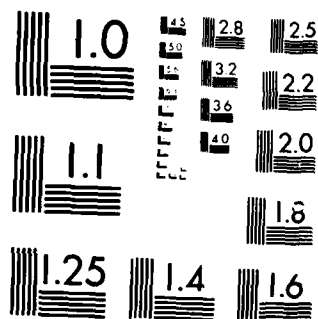
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The Ohio State University

RADAR TARGET CLASSIFICATION STUDIES -  
SOFTWARE DEVELOPMENT AND DOCUMENTATION

by

A. Kamis, F. Garber and E. Walton

The Ohio State University

**ElectroScience Laboratory**

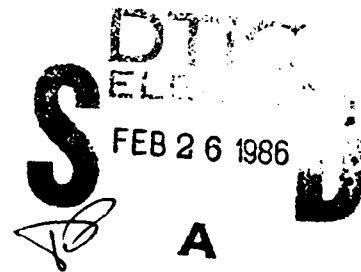
Department of Electrical Engineering  
Columbus, Ohio 43212

Technical Report No. 716559-1

Contract No. N00014-84-K-0705

September 1985

Office of Naval Research  
800 North Quincy Street  
Arlington, Virginia 22217



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ADA 164789

<b>REPORT DOCUMENTATION PAGE</b>		1. REPORT NO.	2.	3. Recipient's Accession No.	
4. Title and Subtitle RADAR TARGET CLASSIFICATION STUDIES - SOFTWARE DEVELOPMENT AND DOCUMENTATION				5. Report Date September 1985	
7. Author(s) A. Kamis, F. Garber and E. Waton				8. Performing Organization Rept. No. 716559-1	
9. Performing Organization Name and Address Ohio State University ElectroScience Laboratory 1320 Kinnear Road Columbus, Ohio 43212				10. Project/Task/Work Unit No.	
12. Sponsoring Organization Name and Address Office of Naval Research 800 North Quincy Street Arlington, VA 22217				11. Contract(C) or Grant(G) No. (C) N00014-84-K-0705 (G)	
				13. Type of Report & Period Covered Technical Report	
15. Supplementary Notes				14.	
16. Abstract (Limit: 200 words)  This report documents the software developed for Technical Report No. 716559-1, generated under Contract No. N00014-84-K-0705. Three computer programs were developed to process and analyze calibrated radar returns. The first program, called DATABASE, was developed to create and manage a random accessed data base. The second program, called FTRAN DB, was developed to process horizontal and vertical polarizations radar returns into different formats (i.e., time domain, circular polarizations and polarization parameters). The third program, called RSSE, was developed to simulate a variety of radar systems and to evaluate their ability to identify radar returns.  Complete computer listings are included in the appendices.					
17. Document Analysis a. Descriptors					
b. Identifiers/Open-Ended Terms					
c. COSATI Field/Group					
18. Availability Statement		19. Security Class (This Report) Unclassified		21. No. of Pages 61	
		20. Security Class (This Page) Unclassified		22. Price	

# INDEX

	Page
INTRODUCTION	1
SECTION 1 PROGRAM - DATABASE	
1.1 INTRODUCTION	1
1.2 MENU LISTING	4
1.2.1 MENU SUMMARY	5
1.2.1.1 ASSIGN COMMAND	6
1.2.1.2 CREATE COMMAND	12
1.2.1.3 DELETE COMMAND	14
1.2.1.4 EXAMINE COMMAND	14
1.2.1.4.1 EX_BASE ROUTINE	14
1.2.1.4.2 EX_ESL ROUTINE	16
1.2.1.4.3 EX_DBM ROUTINE	17
1.2.1.5 HELP COMMAND	18
1.2.1.6 MAP COMMAND	19
1.2.1.7 MODIFY COMMAND	21
1.2.1.8 PHASE COMMAND	21
1.2.1.9 \$ DCL COMMAND	21
1.3 RELATED SOFTWARE	22
1.4 DATA BASE SPECIFICATIONS	23
1.5 NESTING OF MAJOR SUBROUTINES	23
SECTION 2 PROGRAM - FTRAN_DB	
2.1 INTRODUCTION	24
2.2 ORIGINAL FTRAN COMMANDS	24
2.3 MODIFIED FTRAN COMMANDS	29
2.3.1 LDB COMMAND	30
2.3.2 VVP COMMAND	31
2.3.3 HHP, VHP, RCP, LCP, XCP COMMANDS	31
2.3.4 RPC AND LPC COMMANDS	32
2.3.5 DPA COMMAND	35
2.3.6 PUT COMMAND	38
SECTION 3 PROGRAM - RSSE	
3.1 INTRODUCTION	42
3.2 MENU LISTING	42
3.2.1 MENU SUMMARY	43
3.2.1.1 CREATE COMMAND	44
3.2.1.2 CHANGE COMMAND	47
3.2.1.3 DISPLAY COMMAND	47
3.2.1.4 HELP COMMAND	48
3.2.1.5 IDENTIFICATION COMMAND	49
3.2.1.5.1 GENERATE COMMAND	50
3.2.1.5.2 NEAREST COMMAND	53
3.2.1.5.3 DISPLAY COMMAND	55
3.2.1.5.4 HELP COMMAND	57

INDEX continued

	Page
3.2.1.5.5 QUIT COMMAND	57
3.2.1.6 MAP COMMAND	57
3.2.1.7 PLOT COMMAND	59
3.2.1.8 \$ DCL COMMAND	59
3.3 SPECIAL FUNCTIONS	59
3.4 NESTING OF MAJOR SUBROUTINES	60

REFERENCES

APPENDICES - PROGRAM LISTINGS

APPENDIX A	READ DATABASE	A-1
APPENDIX B	DATABASE	B-1
APPENDIX C	FTRAN_DB	C-1
APPENDIX D	RSSE	D-1

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1.1-1        Frequency formatted data base	3
1.2.1.1-1    Merging of Phase data strings	8
1.2.1.1-2    Merging of Amplitude data strings	9
1.2.2.2-3    FORTRAN data record write statement	11
1.2.1.1-4    Display after fourth assignment to record #135	11
1.2.1.2-1    FORTRAN output statements	13
1.2.1.4-1    EX_BASE output	15
1.2.1.4.2-1   EX_ESL output	16
1.2.1.4.3-1   EX_DBM output	17
1.2.1.5-1    HELP routine displays	18
1.2.1.6.3-1   Example DATA BASE	19
1.2.1.6.3-2   MAP output of example DATA BASE	20
1.2.1.6.3-3   Version II MAP output	20
1.3-1        READ_DB subroutine	22
2.2-1        Basic FTRAN comands	24
2.2-2        Ellipsoid Body dimensions	26
2.2-3        0° radar view with 0° tilt angle	26
2.2-4        90° radar view with 60° tile angle	26
2.2-5        Ftran Command Illustration	27
2.2-6        Ftran WIN Command Illustration	28
2.3-1        Additional menu commands	29
2.3.1-1      LDB information block	31

<u>Figure</u>		<u>Page</u>
2.3.2-1	HHP,VHP,RCP,LCP,XCP commands	31
2.3.4-1	Plot menu	32
2.3.4-2	Polarization parameters (rectangular format)	33
2.3.4-3	Polarization parameters (Poincare'format)	33
2.3.5-1	DPA Command Illustration	36
2.3.5-2	Alined and Non-Alined polarizations plotted on a Poincare' plane projection	37
2.3.6-1	Data processing for PUT command illustration	39
2.3.6-2	Result of PUT command	40
2.3.6-3	Poincare' projections of time gated radar returns	41
3.2-1	Main menu	42
3.2.1.1-1	Polarization types	45
3.2.1.1-2	Data matrix display summary	46
3.2.1.2-1	Change parameters sub-menu	47
3.2.1.4-1	Main RSSE Help display	48
3.2.1.5-1	Identification Menu	49
3.2.1.5-1	RSSE radar type menu	51
3.2.1.5.1-2	RSSE radar types	51
3.2.1.5.2-1	Procedures to execute the NEAREST command	54
3.2.1.5.3-2	DISPLAY command example	56
3.2.1.5.4-1	Identification HELP routine display	57
3.2.1.6-1	Illustration of MAP output	58

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
2.3.5-1 DPA conditions	35
3.2.1.6 Data Matrix Error Conditions	57

## INTRODUCTION

The software development for contract #716559 consisted of three tasks. The first task was to develop a data base management program designed to reduce the effort to retrieve calibrated radar data. The second task was to design a program to process horizontal and vertical polarizations radar returns into circular polarization components. The third task was to develop an expandable modularized program to identify a test set of noise corrupted calibrated data strings against a catalog set of "error free" calibrated data strings. The following sections describe key features and show examples of available outputs of the three computer programs.

## SECTION 1

### 1.1 PROGRAM: DATA BASE MANAGER

The Ohio State University Electro-Science Laboratory ( OSU ESL ) has literally thousands of data files on various radar targets at many different aspect angles, frequencies, and polarizations. Handling such a large data set is very difficult and cumbersome. The DATA BASE program provides the user with a means to combine many files that describe a target feature into one large single file called a DATA BASE. The data base file can provide a quick, efficient, and reliable way of retrieving target data by simply specifying the file name, an aspect angle, and polarization type instead of numerous file names previously required.

Some advantages of the data base file are:

- Shared access with other system users.
- Summary listings of available data.
- Compact data storage.
- Random data string access.
- Expandable.

The DATA BASE program was developed in a modular programming style with a menu driven format. The main program body consists mainly of subroutine call statements that are queued by requesting items from the menu. The complete program consists of thirty-two subroutines. This modular style of programming enables the programmer to locate, modify, compile, or add a new subroutine in an efficient manner.

A data base file is essentially an DEC VAX-11 FORTRAN V3.0 "indexed" file that contains many data strings describing a certain radar target feature. Each data string stored in the data base file is assigned to a single record, which is denoted by a primary key and a set of secondary keys. Depending on the keys specified, the assigned data file will be either stored in a previous allocated record, or in a new data record that expands the data base file size. These keys can be defined in any format by a declaration in the open file command.

They allow the user to access files in a variety of methods. The indexed data base file then allows users to access a particular data record in the file by designating the primary key or a set of data records by specifying a secondary key [1].

For frequency formatted data strings the primary key is defined through the use of a simple algorithm:

$$\text{PRIMARY KEY} = \text{ASPECT ANGLE} * 3 + \text{POLARIZATION TYPE} \quad (\text{eq. 1.1})$$

where ASPECT ANGLE is an integer value from 0 to 360 degrees.  
POLARIZATION TYPE is an integer value of either 1, 2, or 3.

Therefore, allowing the primary key to have a unique value for each frequency formatted data string assigned to a data base record.

When a data base is created, the zero primary key record is allocated for bookkeeping. Its function is to keep a map of the data records, allowing a user to see exactly what data exists in the data base for processing. This record also contains four character strings that allow the user to enter a title and additional comments pertaining to the data to be assigned to the data base file.

For future development of the DATA BASE program, additional unused variables were also allocated in each data record

Currently, only frequency formatted data strings can be entered into a data base file. A frequency formatted data string is one where the data is versus frequency and is uniquely described by a target name, polarization type, and an aspect angle. In later versions of the DATA BASE program, the capability to handle angle and time formatted file will be included.

The frequency formatted data strings encountered at OSU ESL facility contain three polarization types and usually aspect angle intervals of no less than five degrees. The three polarization types are: transmit vertical receive vertical ( VV ), transmit horizontal receive horizontal ( HH ), and transmit vertical and receive horizontal ( VH ). The polarizations VV, and HH are called co-polarized components and VH is called a cross-polarized component.

The data base file has been limited to the three polarization types described above and aspect angles from zero to three hundred sixty degrees by one degree increments. Thus allowing the data base to expand to one thousand eighty three data records.

A physical visualization a data base file might be a large box with keyed storage bins. For a frequency formatted file, the data base may be set up as shown in Figure 1.1-1. This figure represents a data base file that would describe a single target at azimuth angles from zero to three hundred sixty degrees by one degree increments for the three polarization types HH, HV, and VH, at one elevation angle.

\*\*\*\*\*

EACH KEY SPECIFIES A RECORD IN THE DATA BASE DEFINED BY  
A ASPECT ANGLE AND A POLARIZATION TYPE.

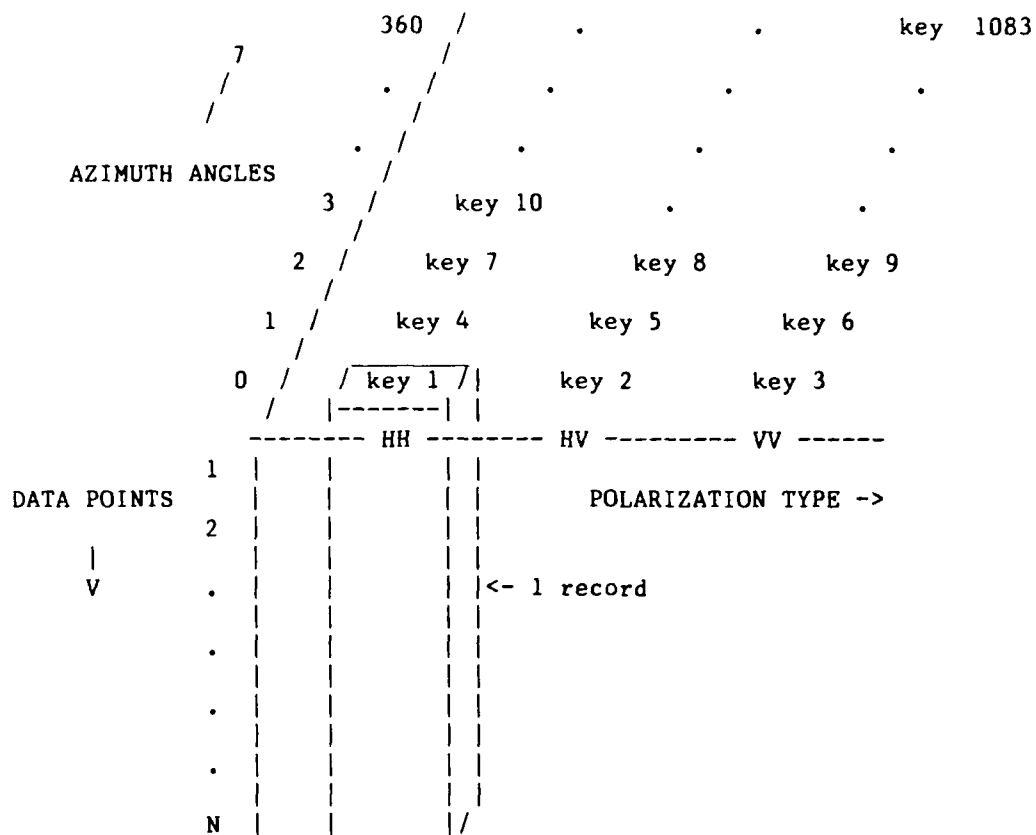


Figure 1.1-1 Frequency formatted data base

\*\*\*\*\*

## 1.2 MENU LISTING

The menu, driven by a loop routine in the main program body, consists of nine commands. These commands called top level commands are displayed in the following manner:

\*\*\*\*\*

### MENU FEATURES

#### TOP LEVEL COMMANDS :

ASSIGN a data file to the data base.  
CREATE a new data base.  
DELETE files from the data base.  
EXAMINE the contents of a file.  
EXIT from program.  
HELP messages.  
MAP the data base.  
MODIFY a file in the data base.  
PHASE adjust an assignment.  
\$ " any VAX/VMS DCL command ".

Type YES or NO for all " ? " default value -> YES  
All commands may be abbreviated to three characters  
Press CTRL C to abort any command

ENTER COMMAND ->

\*\*\*\*\*

### 1.2.1 MENU SUMMARY

A brief introduction to the top level commands are as follows:

**ASSIGN** : Assigns a data file to a record in the data base according to a indexed file record **KEY**. The assignment can either add a new data record or replace/append an existing data record.

**CREATE** : Opens a data base as an indexed file on a user specified or default disk drive.

**DELETE** : Deletes a record from the data base based on the **KEY** the user specifies.

**EXAMINE** : Lets the user examine individual **ESL** data files, **DBM** header files, or **DATA BASE** records.

**EXIT** : Exits the program and returns the user to **VAX/VMS** operation.

**HELP** : Helps the user develop proper execution procedures and corrective measures for program error messages.

**MAP** : Shows the user the current status of records in the data base. That is whether the record is full, partially full, or empty of data points. Additional information on how a data record was assigned is also available in the map routine.

**MODIFY** : Allows the user to open an old data base for new assignments.

**PHASE** : Allows the user to introduce a phase slope offset over a selected range of data points. The phase slope offset is specified in degrees.

**\$ " DCL COMMAND "** : Allows the user to enter a **VAX/VMS DCL** command for execution while the program is running.

The short description of the top level commands listed previously provided a brief introduction into the capabilities of the **DATA BASE** program. We will now discuss, in detail, the workings of the **DATA BASE** commands.

#### 1.2.1.1 ASSIGN

The ASSIGN command operates on ESL range acquired data files only, see ESL report #714190-1. Currently, the files assigned to the data base have only been calibrated target data files but this is not a requirement, un-calibrated ESL files could also be assigned to a data base file as long as the phase reference is centered at the radar target location. Some temporary constraints have been placed on the ESL file type used in assign operation.

These constraints are as follows:

The input ESL file must be a frequency formatted file ( ie. the data points must be taken verses frequency ).

The frequency formatted file must be taken in increment of less then fifty megahertz.

These constraints will be modified in later versions of DATA BASE program when the need arises.

In assigning an ESL file to a data base, the file is first read into a temporary data buffer. After the user views the file header to ensure the assignment of the correct file, the aspect angle and polarization type is entered. Next, the data string buffer is processed through an interpolation routine that reformats the frequency increment a fifty megahertz step. The fifty megahertz step allows data from targets of approximately twenty feet or less to be processed without any loss of information. A Hamming window with a frequency bandwidth of one-hundred megahertz centered about the desired fifty megahertz point is used in the interpolation routine [2]. The reformatting saves memory space and standardizes the data strings which have been taken at various frequency increments. After the reformatting, the data string is then stored in a newly created data base record which is referenced to a set of keys. The keys, defined by the aspect angle and polarization type entered, consists of a primary key, defined in equation 1.1, and two secondary keys which are defined as the aspect angle and polarization type. The two secondary keys are not currently used by the data base program, but they do add extra flexibility in other programs that read data from a data base. The unique primary key that defines each data base record is use for all further DATA BASE program input/output operations. After the data record is created, additional assignments to that record will invoke the append/replace routine.

The append/replace routine allows the user to add additional data or replace all or part of the data string contained in the data record. The append/replace routine was created to handle the ESL frequency formatted file types that were band limited by feed horns and software constraints. The append/replace routine can only process the following situation:

The additional data strings must be overlapping or separated by no more than fifty megahertz.

When an overlap of one hundred megahertz or more exists, the merging of data strings takes place at the closet fifty megahertz increment step value within the overlap. When no overlap exist or the overlap is less then one hundred megahertz, a linear interpolation is executed to project the new data string

to the respective end point ( MERGE POINT ) of the DATA BASE record's data string. The merge point is always at a frequency step value of fifty megahertz and the linear interpolation is executed over a one-hundred megahertz bandwidth starting at the merge point value. Once the merge point is established and the linear interpolation is executed, a process of amplitude and phase data adjustment is carried out [3].

Adjusting phase slope, which is equivalent to a positional adjustment in the time domain, a phase offset is calculated at the merge point of the two data strings and is applied to the entire append/replace data string as a phase slope correction by the algorithm shown in equation 1.2.1.1-1.

$$\text{CORRECTED\_PHASE} = \text{OLD\_PHASE} - \text{PHASE OFFSET} * ( \text{FREQUENCY} / \text{MERGE\_POINT} )$$

Equation 1.2.1.1-1

The phase correction adjusts the new data string to the same phase reference as the DATA BASE record's data string. The phase offset is chosen by calculating the smallest difference of phase between the two data strings within a plus or minus one-half cycle of phase ( ie. 180 to -180 degrees ). This limited range for the phase offset, due to the two pi modulo phase ambiguity, places a constraint on the calibrated targets physical locations. The physical locations of the two calibrated targets must lie within the limits of plus or minus (  $3E08 / ( 2 * \text{MERGE\_FREQUENCY} * 180 )$  ) meters of each other to achieve the proper phase slope adjustment. If the distance between the calibrated target locations lies outside required limit, an additional phase offset of some multiple of three-hundred-sixty degrees must be added to the append/replace data string through the use of the PHASE command.

Merging the amplitude parts of the data strings is a much easier task. The amplitude part of a calibrated data string is the RCS of the target, which is independent of positional displacements along the line of sight ( LOS ) for far-field conditions. Therefore the amplitude part of the data strings should match perfectly when an append/replace operation is executed. But slight inaccuracies, due to mis-alignments ( not LOS displacements ) in repositioning the target between data runs, and the data base's reformatting interpolation routine, cause slight discontinuities between the amplitude data strings to occur. The magnitude of these discontinuities are usually no more than one decibel. To deal with this slight discontinuity, a minimum-squared-error linear interpolation is used to project the append/replace data string to the merge point of the data base record's data string. The final value at the merge point is then calculated by taking the average of projected interpolated value and the data base's merge point value. Also, an additional smoothing around the discontinuity is provided by weighting six additional points around the merge point. These points represent a three-hundred megahertz bandwidth, and are weighted by the following algorithms;

$$\begin{aligned} \text{AMP}( M + 1 ) &= \text{AMP}( M + 1 ) + ( \text{AMP}( M ) - \text{AMP}( M + 1 ) ) * i * .12 \\ \& \text{ AMP}( M - 1 ) &= \text{AMP}( M - 1 ) + ( \text{AMP}( M ) - \text{AMP}( M - 1 ) ) * i * .12 \\ \text{for } i &= 1, 2, 3, \text{ and where } M \text{ is the merge point's array index value.} \end{aligned}$$

Figures 1.2.1.1-1 and 1.2.1.1-2 illustrate the merging process of four ESL data files at two, four, and six gigahertz for both phase and amplitude data.

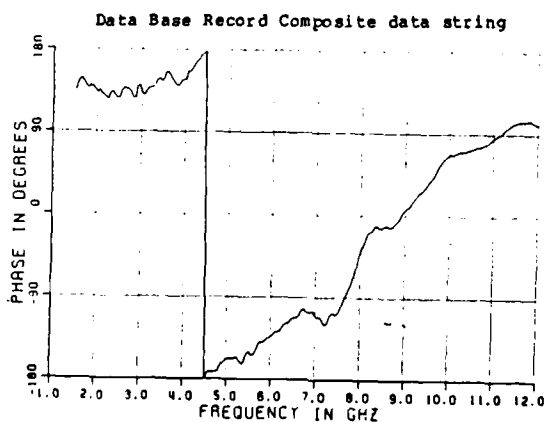
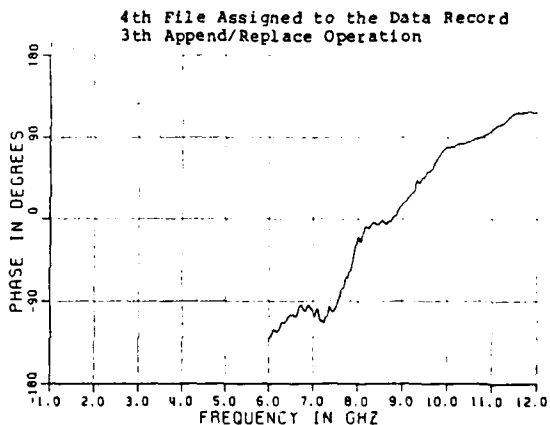
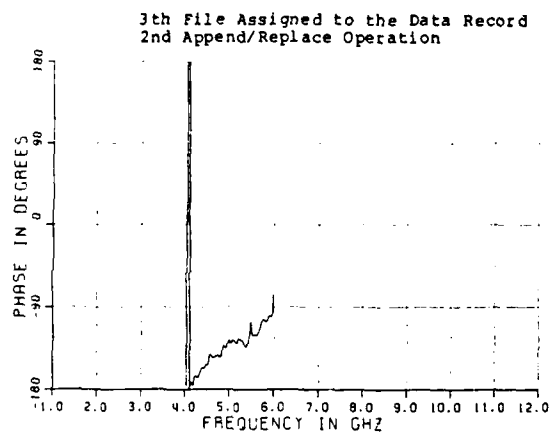
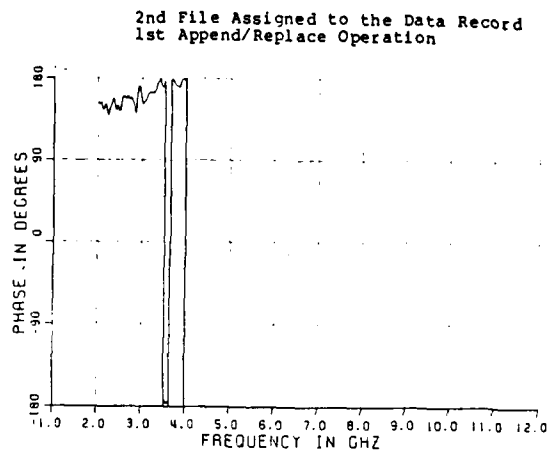
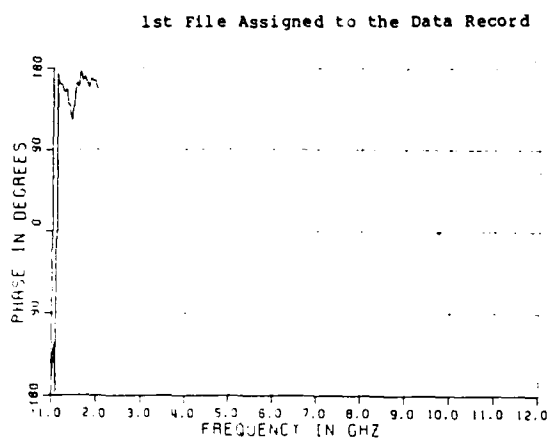


Figure 1.2.1.1-1

Merging of Phase data strings

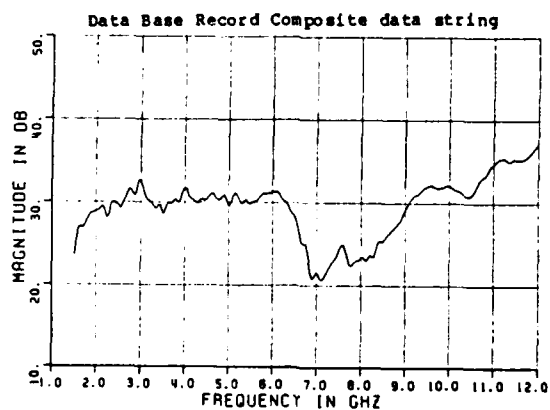
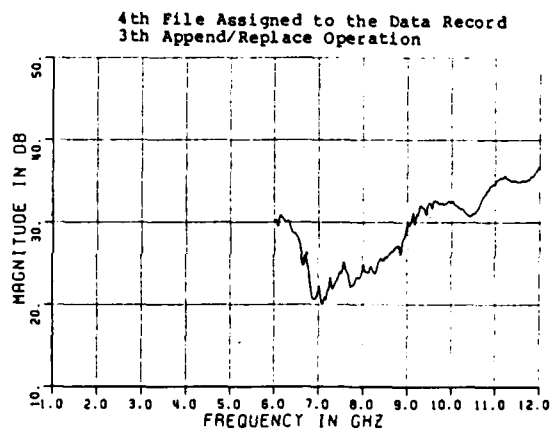
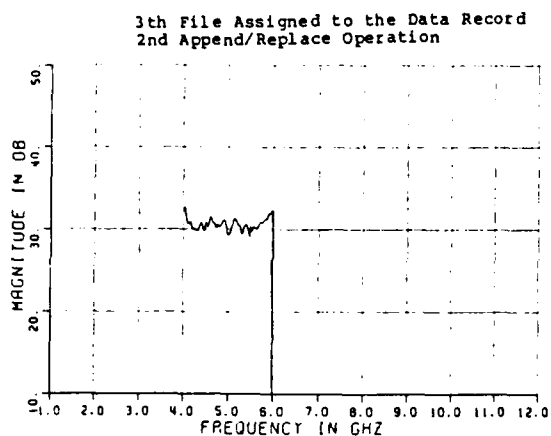
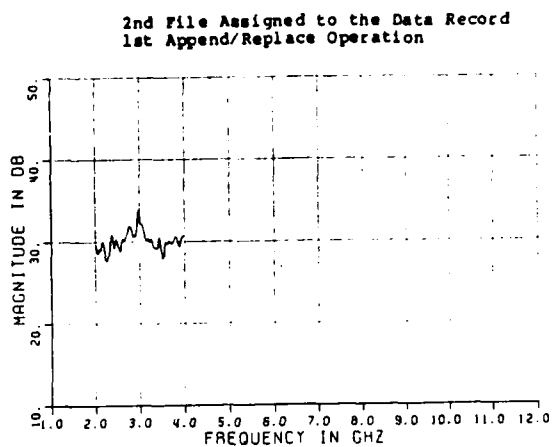
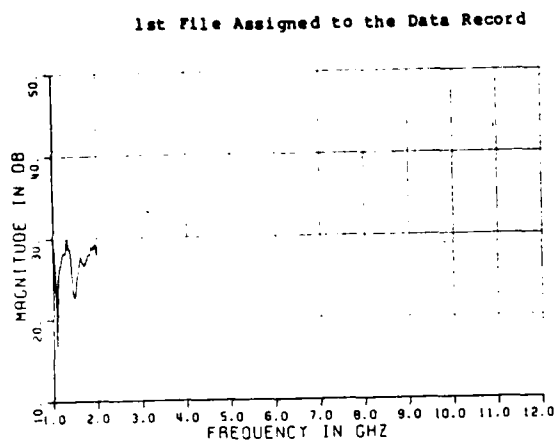


Figure 1.2.1.1-2

Merging of Amplitude data strings

Currently the total composite of any assignments to the a data base record is limited to a lower frequency cutoff of one gigahertz and a upper frequency cutoff of eighteen gigahertz. If a assigned data string goes beyond this range a truncation will occur. Additionally, no more than five assignments can be made to a DATA BASE record ( ie. only four append/replace operations to a DATA BASE record are allowed ).

On completion of the ASSIGN command operations the data stored in the data base record consists of the reformatted amplitude and phase data, the phase adjustment value, the first header line of the assigned file, and the start and stop frequencies of the assigned data string. The data base record, reference by the primary key, stores the phase and amplitude data as a string of unformatted two byte integers to achieve a more compact file organization. To use the integer format, the floating point amplitude and phase data is multiplied by one-hundred and converted to an integer. The range for a two byte ( sixteen bits ) integer is approximately plus to minus-thirty-two-thousand-seven-hundred, using one bit as a sign bit. With this format, the floating point data must be in the range of plus to minus three-hundred-twenty-seven with a resolution of one one-thousandth. For ESL data, the phase can be in either a zero to three-hundred-sixty degree format or a plus to minus one-hundred-eighty degree format. If the the phase data is in the zero to three-hundred-sixty degree format, it is automatically converted to the plus to minus one-hundred-eight format when read into the data base program. The amplitude data is calibrated to decibel-square-centi-meter and is usally never greater then one-hundred decibels in un-scaled form. So, with a multiplication factor of one-hundred, both the amplitude and phase data arrays can fit into the two byte integer format without any loss of information. The two data arrays that store the data string are called INT\_AMP and INT\_PHASE.

Four other arrays, called ST\_BASE, STP\_BASE, PHA\_OFF, and HEAD, are stored in the DATA BASE data record with five elements each. The five elements correspond to the five data record assignments that are allowed. The arrays contain information on the start and stop frequencies of each assigned data string, the phase adjustment values calculated to merge the data strings, and the first header line of each of the assigned data files. Two integer variables called STATUS and TIME, also stored in the data record, indicate whether the file is full or partially full, and how many assign operations have been executed on the data record, respectively. Unused variables are allocated in each record for future program modifications.

The main routines called when a ASSIGN command is executed are the ASSIGN, ASPPOL, READFILE, OPEN, STOREF, and APPEND subroutines. The FORTRAN write statement for the allocation of the data base data records are shown in Figure 1.2.1.1-3.

Figure 1.2.1.1-4 represents a typical display the user will receive after the completion of an assignment to the data base.

```

*****

CHARACTER      HEAD( 5 ) * 60, CDUMMY * 5
REAL * 4       RDUMMY, ST BASE( 5 ), STP BASE( 5 ), PHA_OFF( 5 )
INTEGER * 2    INT AMP( 350 ), INT PHASE( 350 )
INTEGER * 4    PRIMARY_KEY, KEY_TWO, KEY_THREE, IDUMMY, STATUS, TIMES

C
C
C      write statement for data records

WRITE( UNIT = DB_UNIT, ERR = 995 )
$      PRIMARY_KEY, KEY_TWO, KEY_THREE,      ! keys
$      CDUMMY, CDUMMY, RDUMMY, RDUMMY,      ! unused variables
$      IDUMMY, IDUMMY, STATUS, TIMES,      ! unused & status variables
$      ( ST BASE( I ), I = 1, 5 ),          ! start freq for 5 assignments
$      ( STP BASE( I ), I = 1, 5 ),          ! stop freq for 5 assignments
$      ( PHA_OFF( I ), I = 1, 5 ),          ! phase adjustment values
$      ( HEAD( I ), I = 1, 5 ),             ! headers from original files
$      ( INT AMP( I ), I = 1, 341 ),        ! reformatted amplitude data
$      ( INT PHASE( I ), I = 1, 341 )      ! reformatted phase data

C
C

```

Figure 1.2.1.1-3 FORTRAN data record write statement

```

*****

ASPECT ANGLE = 45
POLARIZATION = VV

ASSIGNMENT IS A PARTIAL RECORD
CONSISTING OF :

FIRST INPUT OPERATION -
JL09C0 1:27 45 ASP LARGE 747
WITH FREQUENCIES : 6.00 to 12.00 GHz
AND WITH A PHASE CORRECTION OF 0.00 DEGREES
FIRST APPEND/REPLACE OPERATION -
JL09H5 2:49 45 ASP LARGE 747
WITH FREQUENCIES : 4.00 to 6.00 GHz
AND WITH A PHASE CORRECTION OF 157.09 DEGREES
SECOND APPEND/REPLACE OPERATION -
JL09F8 1:15 45 ASP LARGE 747
WITH FREQUENCIES : 2.00 to 4.00 GHz
AND WITH A PHASE CORRECTION OF 98.80 DEGREES
THIRD APPEND/REPLACE OPERATION -
JL09E1 11:35 45 ASP LARGE 747
WITH FREQUENCIES : 1.00 to 2.00 GHz
AND WITH A PHASE CORRECTION OF 55.60 DEGREES

```

Figure 1.2.1.1-4 Display after fourth assignment to record # 135

```

*****

```

### 1.2.1.2 CREATE

The CREATE command initially opens and creates a new data base as an "indexed" FORTRAN file [1]. The file can expand to an approximate length of three mega bytes.

When the file is first created the first record is allocated for a bookkeeping function. The first record contains three key variables, one file type variable, five unused variables, four character strings of sixty bytes each, and an integer array of one-thousand-eighty-six elements. The first key variable, required to be unique by indexed organization of the data base file, is set to zero and designated as the "primary key" in the open statment. The second and third keys, which are not required to be unique, are also set to zero. The file type variable called KIND is either set to "FRE", "ANG", or "TIM", depending on the first file type assigned to the newly created data base. Currently the DATA BASE program can handle only frequency formatted ESL data files on the ASSIGN command, thus the KIND variable is presently set to "FRE" to designate a frequency formatted data base file. Future developement of the data base program will enable time and angle formmated ESL file types to be stored in a data base file format. The five unused variables, which are also allocated for future growth, consists of two character string variables of five bytes each, two four byte real variable, and one four byte integer variable. The four sixty byte character strings contain the title and additional comments pertaining to the data base. The actual bookkeeping function of the first record is done by the one-thousand-eighty-six element integer array called REC\_STATUS. The REC\_STATUS array, which is an array of two byte integers, creates a map of the status of the records in the data base. Each element of the REC\_STATUS array represents a record in the data base which in turn represents a particular aspect angle at one of the three polarization types. The array stores a value of either one, two, or three to indicate the status of a data record. A value of one in an array element position is defined as a null data record; a value of two is defined as a partially filled data record; a value of three indicates the the data record is full. For example, a value of three in the REC\_STATUS array element number two for a frequency formmated data base informs the user when a MAP command is executed that the aspect angle of zero degrees and cross-polarization "VH" data record is completely full of data ( ie. the record contains amplitude and phase data from one to eighteen gigahertz by fifty megahertz steps ). Whenever an ASSIGN or a DELETE command is executed the REC\_STATUS array is updated accordingly and rewritten into the first record.

The main routines called when a CREATE command is executed are the CREATE and OPEN subroutines. The FORTRAN open file statement and the FORTRAN write statements for the allocation of the first record for a data base file are shown in Figure 1.2.1.2-1. An explantion of the qualifiers inside the open statement can be found in the VAX FORTRAN software manual [1].

```

C      CHARACTER      TITLE * 60, COMMENT * 60, KIND * 3, CDUMMY * 5
C      REAL * 4      RDUMMY
C      INTEGER * 2    REC_STATUS ( 1086 )
C      INTEGER * 4    PRIMARY_KEY, KEY_TWO, KEY_THREE, IDUMMY

C      open statement for a data base

C      OPEN( UNIT = DB_UNIT, NAME = DATA_BASE, ACCESS = 'KEYED',
$      KEY = ( 1:4:INTEGER, 5:8:INTEGER, 9:12:INTEGER ),
$      TYPE = 'NEW', FORM = 'UNFORMATTED',
$      RECORDTYPE = 'VARIABLE', RECORDSIZE = 2500, SHARED,
$      ORGANIZATION = 'INDEXED', ERR = 999 )

C      write statement for first "bookkeeping" record

C      WRITE( UNIT = DB_UNIT, ERR = 995 )
$      PRIMARY_KEY, KEY TWO, KEY THREE, KIND,      ! keys
$      CDUMMY, CDUMMY, RDUMMY, RDUMMY, IDUMMY,      ! unused variables
$      TITLE, ( COMMENT( I ), I = 1, 3 ),           ! DB title & comments
$      ( REC_STATUS ( I ), I = 1, 1086 )             ! DB bookkeeping array

C      CLOSE( UNIT = DB_UNIT, ERR = 988 )

```

Figure 1.2.1.2-1      FORTRAN output statements

### 1.2.1.3 DELETE

The DELETE command enables the user to delete any data record from the data base by entering the primary key value. For a frequency formatted, file the user is prompted for the aspect angle and the polarization type so the primary key can be calculated. After the data record is deleted from the data base, the bookkeeping array element of the first record, REC\_STATUS( PRIMARY\_KEY ), is reset to one and a response is displayed to the user verifying the operation. The main routine called when a DELETE command is executed is the delete subroutine.

### 1.2.1.4 EXAMINE

The EXAMINE command allows the user to display three types of data files. The three files types are; ESL data files ( ESL report #714190-1 ), DBM header files, and the DATA BASE files described in this section. After the EXAMINE command is executed, the following sub menu will appear.

EXAMINE MODE  
ENTER ONE OF THE FOLLOWING FILE TYPES:

DBM header file  
ESL single data file  
DATA BASE file

ENTER FILE TYPE ->

After selecting one of the three sub commands, either the EX\_DBM, EX\_ESL, or EX\_BASE, subroutine will be executed.

#### 1.2.1.4.1 EX\_BASE

The EX\_BASE subroutine displays information contained in a data record of the data base requested. The data base currently under assignment is the default data base if no data base name is entered. If the data base is frequency formatted type, the user is prompted for the aspect angle and the polarization type so the primary key can be formulated. Once the primary key is calculated, the corresponding data record is displayed. The display contains information on how the data record was constructed and the values of the data strings contained in the record. The data values for a frequency formatted data base are displayed in amplitude and phase versus frequency in gigahertz, where the amplitude values are displayed in decibels and the phase in degrees. The user can also request a selected range of data point or default to the entire data string. An example of a display from the EX\_BASE subroutine is shown in Figure 1.2.1.4-1.

\*\*\*\*\*

ASPECT ANGLE = 45  
POLARIZATION = VV

ASSIGNMENT IS A PARTIAL RECORD  
CONSISTING OF :

FIRST INPUT OPERATION -

JL09C0 1:27 45 ASP LARGE 747  
WITH FREQUENCIES : 6.00 to 12.00 GHz  
AND WITH A PHASE CORRECTION OF 0.00 DEGREES

FIRST APPEND/REPLACE OPERATION -

JL09H5 2:49 45 ASP LARGE 747  
WITH FREQUENCIES : 4.00 to 6.00 GHz  
AND WITH A PHASE CORRECTION OF 157.09 DEGREES

SECOND APPEND/REPLACE OPERATION -

JL09F8 1:15 45 ASP LARGE 747  
WITH FREQUENCIES : 2.00 to 4.00 GHz  
AND WITH A PHASE CORRECTION OF 98.80 DEGREES

THIRD APPEND/REPLACE OPERATION -

JL09E1 11:35 45 ASP LARGE 747  
WITH FREQUENCIES : 1.00 to 2.00 GHz  
AND WITH A PHASE CORRECTION OF 55.60 DEGREES

SELECTED FREQUENCY RANGE 11300 MHz to 12222 MHz

FREQUENCY (GHZ)	AMPLITUDE (DB)	PHASE (DEG)
11.300	4.140	-80.440
11.350	1.760	-60.050
11.400	2.640	-32.620
11.450	4.270	-21.550
11.500	5.380	-13.980
11.550	6.780	-4.810
11.600	8.320	-2.220
11.650	8.790	-6.010
11.700	8.690	-8.850
11.750	8.900	-11.680
11.800	9.050	-16.740
11.850	8.760	-23.850
11.900	7.530	-29.250
11.950	6.810	-33.560
12.000	6.970	-37.290
12.050	0.000	0.000
12.100	0.000	0.000
12.150	0.000	0.000
12.200	0.000	0.000

Figure 1.2.1.4-1 EX\_BASE output

\*\*\*\*\*

#### 1.2.1.4.2 EX\_ESL

The EX\_ESL subroutine allows the user to display the header and data information contained in an ESL file type. The user is first prompted for a ESL file name. The data file can either be formatted as a frequency, angle, or time, file type. Once the header is displayed the user can select a part of the data string, or default to the entire data string for display. For frequency formatted files the values of data are displayed in amplitude ( decibels ) and phase ( degrees ) versus frequency in gigahertz. For angle formatted files the data values are also displayed in amplitude ( decibels ) and phase ( degrees ) but the value is versus aspect angle in degrees rather than frequency. For a time file the data values are displayed as the magnitude of an impulse versus time in nanoseconds. An example of a display from the EX\_ESL subroutine is shown in Figure 1.2.1.4.2-1.

\*\*\*\*\*

A4048I 50 DEG AZ - 727 1.-12.-10 L727-1  
A=A/B=40 B=35 BW=4 AV=1 RES=ON SRCH=20 HP FEED=O/U  
NL1100 FF= 1000.IN= 10. \ RMM/PB 17-FEB-84

SELECTED FREQUENCY RANGE 1000 MHz to 12200 MHz

FREQUENCY (GHZ)	AMPLITUDE (DB)	PHASE (DEG)
1.0000	1.8600	172.3000
1.0100	-4.1600	142.9000
1.0200	-7.0600	140.5000
1.0300	0.4700	97.9000
1.0400	4.4400	42.5000
1.0500	1.8500	-3.1000
1.0600	-1.6300	-9.9000
1.0700	4.3000	-27.5000
1.0800	6.5900	-82.3000
1.0900	4.8500	-140.0000
1.1000	-3.7700	-175.7000
1.1100	3.6300	-136.8000
1.1200	7.6200	151.2000
1.1300	6.4700	81.2000
1.1400	-3.3700	29.1000
1.1500	1.2100	100.9000
1.1600	6.9800	28.0000
1.1700	6.6600	-42.9000
1.1800	-1.6000	-115.1000
1.1900	-1.5000	-19.4000
1.2000	6.1800	-97.8000
1.2100	5.8300	-166.9000
1.2200	-0.2600	119.7000

Figure 1.2.1.4.2-1 EX\_ESL output

\*\*\*\*\*

#### 1.2.1.4.3 EX\_DBM

The EX\_DBM subroutine allows the user to display information contained in a data base manager ( DBM ) header file.

The DBM header file is a file that is created when the data taken on the ESL RANGE, is transferred to the DEC VAX11/780 main ESL processing computer. The DBM header file only stores the header from all the data files requested for transfer. The information stored is contained in the first one-hundred-eighty bytes of the ESL data files and contains documentation on the type of file ( ie. frequency, angle, of time ) on the first line ( or first sixty bytes ), receiver settings or calibration file names on the second line, and number of points, starting point, increment and initials of the person who took the data on the third line. A search routine imbedded in the EX\_DBM subroutine allows the user to search the DBM header file for particular character strings. The search routine allows up to five search strings to be entered and each search string can contain up to sixty characters. An example of a DBM header file display with a three string search is listed in Figure 1.2.1.4.3-1.

```
*****  
  
SEARCH STRING # 1 :  STRIP  
SEARCH STRING # 2 :  90 DEG  
SEARCH STRING # 3 :  45 DEG  
  
STRINGS FOUND IN 727:727.DBM      TYPE --> FREQUENCY  
  
A4073B  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP  
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4  
NL1100 FF= 1000.IN=  10. \JDB/ RMM 13-MAR-84  
  
STRINGS FOUND IN 727:727.DBM      TYPE --> FREQUENCY  
  
A4073N  90 DEG  2X15 CM STRIP @ 45 DEG  1.-12.-10 XP  
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4  
NL1100 FF= 1000.IN=  10. \JDB/ RMM 13-MAR-84  
  
STRINGS FOUND IN 727:727.DBM      TYPE --> FREQUENCY  
  
B4073C  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP  
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4  
NL1100 FF= 1000.IN=  10. \JDB/ RMM 13-MAR-84  
  
STRINGS FOUND IN 727:727.DBM      TYPE --> FREQUENCY  
  
B4073L  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP  
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4  
NL1100 FF= 1000.IN=  10. \JDB/ RMM 13-MAR-84
```

Figure 1.2.1.4.3-1 EX\_DBM output

```
*****
```

The main routines called when a EXAMINE command is executed is the EXAMINE subroutine and either the EX\_BASE, EX\_ESL, or EX\_DBM subroutines. All EX subroutines provide the user with an option to acquire a hard copy of the displayed information.

#### 1.2.1.5 HELP

The HELP command provides the user with information pertaining to the top level commands, error messages, and additional software that uses the data base format. The HELP command is supported by the DEC VAX/VMS V4.0 system software and allows the help routine to be set up in a multi level structure ( ie. the help topics branch down to subtopics ) [4], [5]. Figure 1.2.1.5-1 shows the major help topics currently available to the user, and an example of a help message display.

\*\*\*\*\*

Information available:

ASSIGN	AUTHOR	CREATE	DELETE	ERRORS	EXAMINE	MAP
MENU	MODIFY	PHASE	PROGRAMS	START_UP	USER_SUBS	

Topic? ASSIGN

Assigns a data file to a record in the data base according to a indexed file's record KEY. The assignment KEY is based on two specified parameters such as the aspect angle and the polarization type for a frequency formatted data base.

KEY = ASPECT ANGLE \* 3 + POLARIZATION TYPE

Additional information available:

APPEND/REPLACE      EXAMPLE

Sub Topic?

Figure 1.2.1.5-1      HELP routine displays

\*\*\*\*\*

### 1.2.1.6 MAP

The MAP commands allows the user to list the current status of records in a data base file. The mapping shows the user whether the data records in the data base are full, partially full, or empty of data points. Also, information on record assignments, as shown in Figure 1.2.1.1-4, is available. For a frequency formatted data base, the mapping lists only aspect angles that have records allocated ( ie. contains data in at least one of the polarization types ). A record is defined as full when the data string starts at one gigahertz and ends at eighteen gigahertz.

The Figure 1.2.1.6-1 shows the output of the map routine for an example data base illustrated in Figure 1.2.1.6-2. The example data base only contains data in six records, three are completely full and the other three are partially full. The mapping also reveals that data only exists at four aspect angles and two polarization types. Later versions of the DATA BASE program will incorporate the start and stop values of the data string instead of the words PART and FULL as shown in Figure 1.2.1.6-3.

\*\*\*\*\*

EXAMPLE : OUTPUT OF MAP ROUTINE ( FREQUENCY FORMATTED DATA BASE )

ASPECT ANGLES	7	360	NULL	NULL	PART
	.	.	NULL	NULL	NULL
	.	.	NULL	NULL	NULL
	3		FULL	NULL	NULL
	2		FULL	NULL	PART
	1		NULL	NULL	NULL
	0		PART	NULL	FULL
			HH	HV	VV
	1		POLARIZATION TYPE ---->		
	2				
	3		DATA POINTS		
	.				
	341				

Figure 1.2.1.6.3-1 Example DATA BASE

\*\*\*\*\*

\*\*\*\*\*

MAP OUTPUT FOR DATA BASE AS SHOWN ABOVE

DATA BASE NAME

TITLE: \*\*\*\*\*

COMMENTS: \*\*\*\*\*

ASPECT ANGLE (Deg)	POLARIZATION TYPE		
	HH	HV	VV
0	PART	NULL	FULL
2	FULL	NULL	PART
3	FULL	NULL	NULL
360	NULL	NULL	PART

ADDITIONAL INFORMATION ?

Figure 1.2.1.6.3-2 MAP output of example DATA BASE

\*\*\*\*\*

\*\*\*\*\*

ASPECT ANGLE (Deg)	POLARIZATION TYPE		
	HH	HV	VV
0	1-6	NULL	1-18
2	1-18	NULL	1-12
3	1-18	NULL	NULL
360	NULL	NULL	12-18

Figure 1.2.1.6.3-3 Version II MAP output

\*\*\*\*\*

#### 1.2.1.7 MODIFY

The MODIFY command allows the user to open an existing data base for further assignments, deletions, or phase adjustments of data records. The MODIFY command can also change the default data base to the data base under modification.

#### 1.2.1.8 PHASE

For a frequency formatted data base, the phase offset, in degrees, is referenced to the starting point of the selected string and causes a positional displacement in the data string according to the algorithm ;

$$\text{POSITIONAL\_DISPLACEMENT} = ( \text{PHASE\_OFFSET} * 300 ) / ( 2 * 360 * \text{FREQ} ) \text{ meters}$$

where FREQ is in MHz and PHASE\_OFFSET is in degrees.

The PHASE command allows the user to make fine adjustment to an append/replace string if the ASSIGN command's auto phase adjustment ( see Section 1.2.1.1 ) is in error. This error condition occurs when the LOS positional displacement of the target is greater than one cycle of phase at the merging frequency of the two data strings. The PHASE command is also useful to align the three polarization components HH, HV, and VV at a given aspect angle to a common positional reference. Whenever the PHASE command is executed, the stored phase offset array " PHA\_OFF " ( see Figure 1.2.1.1-3 ) is updated.

#### 1.2.1.9 \$ DCL COMMAND

The \$ DCL command allows the user to execute VAX/VMS command language statements without terminating the program session. DCL commands, such as DIRECTORY, and SEARCH are very complementary to the data base program [4].

### 1.3 RELATED SOFTWARE

As part of this contract effort, two new programs have been written to utilize the data base file structure. These two programs are FTRAN\_DB, and RSSE. The FTRAN\_DB program utilizes the data base for data analysis and the RSSE program uses the data base for target identification analysis. These two programs, also documented in this report, provide powerful analytical tools that take advantage of the ease and efficiency of the data base file format.

A subroutine called DB\_READ has been written to furnish the user with a routine to read a data record from a frequency formatted data base. The subroutine statement, as shown in Figure 1.3-1, has fourteen passed parameters, the first four are inputs, the next two are either inputs or outputs, and the last eight are outputs. Detailed documentation on the subroutine pass parameters can be found in Appendix I.

```
*****  
SUBROUTINE READ_DB( DATA_BASE, DB_UNIT, INP, OUT,  
$      INT_ASP, POL_TYPE,  
$      AMP, PHASE, STATUS, STF, STPF, TITLE, COMMENT, ERR )
```

Figure 1.3-1 READ\_DB subroutine

```
*****
```

#### 1.4 DATA BASE SUMMARY

##### DATA FILE INPUTS TYPES:

ESL DATA FILE TYPES      REPORT # 714190-1

DATA BASE OUTPUT: INDIVIDUAL DATA FILES ARE ASSIGNED TO INDIVIDUAL RECORDS IN THE DATA BASE ACCORDING TO A SPECIFIED KEY.

##### DATA STORAGE :

2500 BYTES PER RECORD  
682 DATA POINTS PER RECORD  
2 BYTES PER DATA POINT  
1084 RECORDS

##### DATA RANGE AND RESOLUTION :

DATA POINT MAX - MIN VALUES : +- 327  
DATA POINT RESOLUTION : 0.01

##### FREQUENCY FORMATTED DATA BASE :

OUTPUT DATA BASE RECORD - 1 to 18 GHz by 50 MHz  
341 AMPLITUDE POINTS  
341 PHASE POINTS

##### ANGLE FORMATTED DATA BASE :

OUTPUT DATA BASE RECORD - 0 to 360 degrees by "TBD"  
"TBD" AMPLITUDE POINTS  
"TBD" PHASE POINTS

##### DATA RECORD OPERATIONS :

FOUR APPEND/REPLACE

#### 1.5 NESTING OF MAJOR SUBROUTINES

##### DATABASE

ASSIGN	CREATE	DELETE	EXAMINE	MAP	MODIFY	PHADJ
ASPPOL	GETNAME	ASPPOL	EX_BASE	GETNAME	GETNAME	OPEN
READFILE	OPEN	OPEN	ASPPOL	OPEN		ASPPOL
OPEN			OPEN	ASPPOL		CORRECT
STOREF			SECLIST	READ_DB		
INTHAM			EX DBM			
OPEN			GETRECORD			
APPEND			EX ESL			
CORRECT			READFILE			
INTHAM			SECLIST			
OPEN						

## SECTION 2

### 2.1 PROGRAM: FTRAN\_DB

The FTRAN\_DB program is a modification of existing ESL "FTRAN" software. The FTRAN\_DB modifications allow the program user to access a data base formatted file ( see Section 1 ) and to create circular polarization components from the linear polarizations HH, VV, VH.

### 2.2 BASIC FTRAN COMMANDS

The FTRAN program was originally written to implement calibration, Fourier transforms, filtering, time gating, and plotting for frequency or time formatted ESL data files. A listing of the original FTRAN commands are shown in Figure 2.2-1.

\*\*\*\*\*

#### ORIGINAL FTRAN COMMANDS

REA : READ AN UNFORMATTED FILE  
RED : READ A FORXXX.DAT FILE  
WRI : CREATE A NEW FILE WITH CURRENT DATA  
LAB : WRITE IN OR CHECK CURRENT LABEL  
PRI : TYPE OUT CURRENT DATA IN DB  
FAS : ADD/SUBTRACT TWO FREQUENCY FILES  
PHD : REMOVE POSITIONAL ERROR VIA PHASE ADJUST  
SMO : SMOOTH DATA POINTS VIA A HAMMING WINDOW  
MDF : MANUALLY MODIFY FILE DATA POINTS  
MOV : ASSIGN CONTENTS OF MAIN ARRAY TO A BUFFER  
CAL : TARGET CAL. WITH BACKGRD/SPHERE DATA  
CRF : CREATE A FREQUENCY FILE TO BE TRANS  
SCD : SCALE LOW FREQUENCY DATA  
RAY : ADD RAYLEIGH PORTION TO THE SPECTRUM  
WIN : WINDOW THE FREQUENCY DOMAIN DATA  
GAT : GATES A DESIRED PORTION OF A TIME DOMAIN SIG  
TAS : ADD/SUBTRACT TWO TIME FILES  
CON : MDF PLOT LABELS AND SCALE FACTORS  
FFT : FREQ. TO TIME DOMAIN TRANS  
IFT : TIME TO FREQ DOMAIN TRANS  
APP : AMPLITUDE AND PHASE PLOT  
RPL : RECTANGULAR PLOT CURRENT DATA  
POL : VECTOR PLOT OF THE AMPLITUDE AND PHASE DATA  
EXI : TERMINATE THIS PROGRAM SESSION

Figure 2.2-1 Basic FTRAN commands

\*\*\*\*\*

The basic FTRAN commands provide useful tools in analyzing calibrated radar data. Six of the most useful commands in analyzing the data are ; the IFT, RPL, GAT, WIN, FFT, and APP, commands. The IFT ( inverse fast Fourier transform ) command, transforms frequency domain data into the time domain. The time domain data is displayed through the use of an RPL ( rectangular plot ) command and is formatted as the response to an impulse excitation versus time in nanoseconds. Transforming to the time domain allows the target response to be analyzed as a function of distance, which allows the user to discriminate and isolate scattering mechanisms. For example, after the scattering mechanisms have been isolated through the use of the GAT ( time gate ) command, the data can be transformed back to the frequency domain through the use of the FFT ( fast Fourier transform ) command and plotted with an APP ( amplitude phase plot ) command. The WIN ( window ) command allow the user to pass the frequency domain data through a band pass or low pass filter. The filtering helps reduce the ringing effect ( ie. Gibbs phenomenon ) caused by the discontinuous frequency data string when the IFT, RPL command sequence is performed. Caution should be used when using the window command if the time domain data is to be transformed back to the frequency domain. Distortion in the RCS of the target is introduced by a bandpass or low pass filter whenever the window command is used.

Figures 2.2-5 and 2.2-6 illustrate these command procedures with data obtained from an ellipsoid body at a tilt angle of zero degrees ( see Figure 2.2-3 ). Plot(a) shows the result of the APP command executed on the amplitude and phase calibrated RCS data for the HH ( transmit horizontal receive horizontal ) polarization obtained in the ESL compact range. Plot(b) shows the result of the RPL command after the IFT command has been executed on the data contained in plot(a). Plot(b), shows that the major scattering center of the ellipsoid body is at approximately -1.05 nanoseconds, and the creeping wave mechanisms along the top to bottom, and side to side, are at approximately 1.3 nanoseconds. A useful rule of thumb is that one nanosecond of time corresponds to 11.8 inches, or one foot in space. Plot(d) shows the result of the GAT command applied to the energy contained in the major scattering center, and plot(f) shows the time gate command applied to energy spectrum of the other scattering mechanisms. The plots( c & e ) show the amplitude results of the FFT command applied to the data in the RPL plots( d & f ). In Figure 2.2-6, plot(g) and plot(b) are used to illustrate the effect of the WIN command. Plot(g), the result of the WIN, IFT, RPL command sequence, compared to plot(b) ( shown again in Figure 2.2-6 for ease of comparison ) shows the reduction in the ringing effect when window command is performed.

In Appendix 3, a user guide for the the basic FTRAN commands is included.

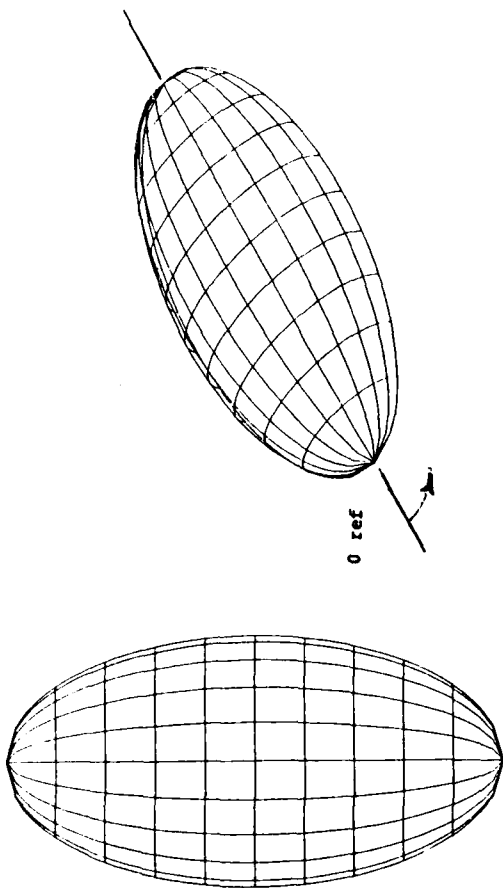


Figure 2.2-2 Ellipsoid Body dimensions.

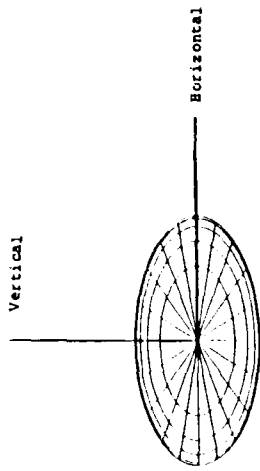


Figure 2.2-3 0° radar view with 0° tilt angle

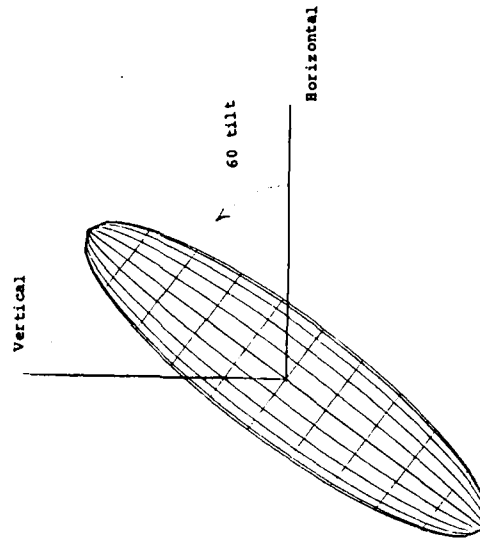


Figure 2.2-4 90° radar view with 60° tilt angle

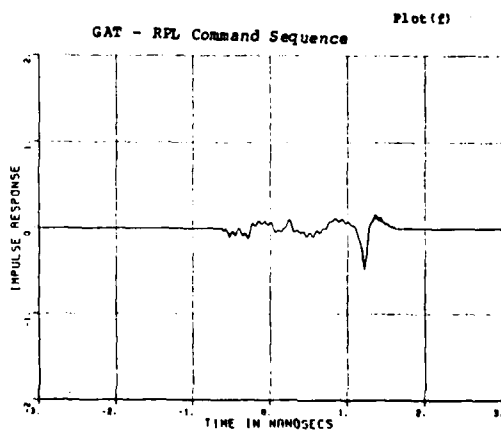
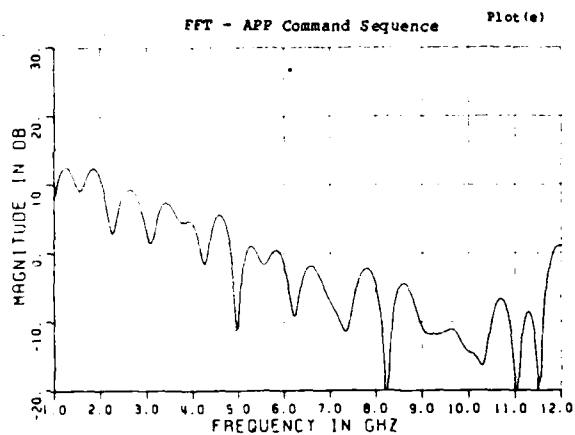
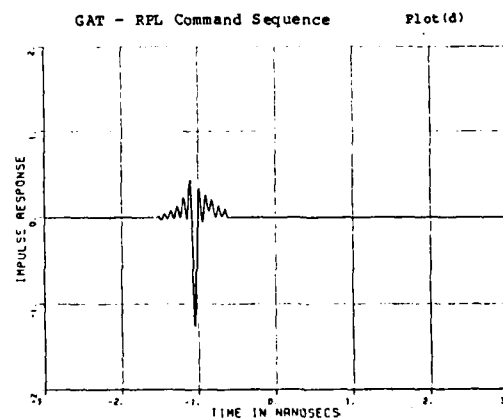
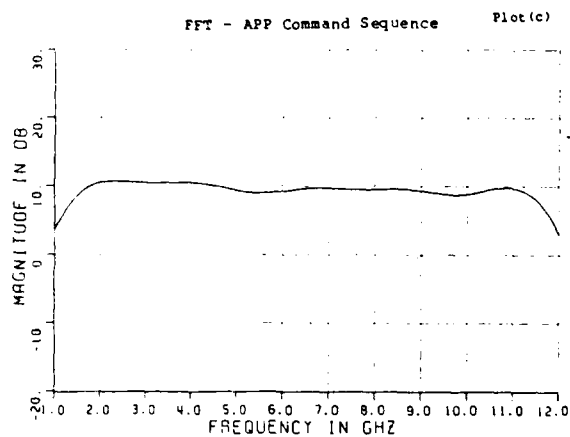
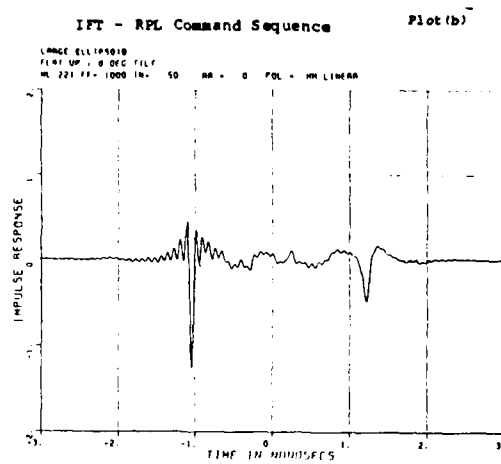
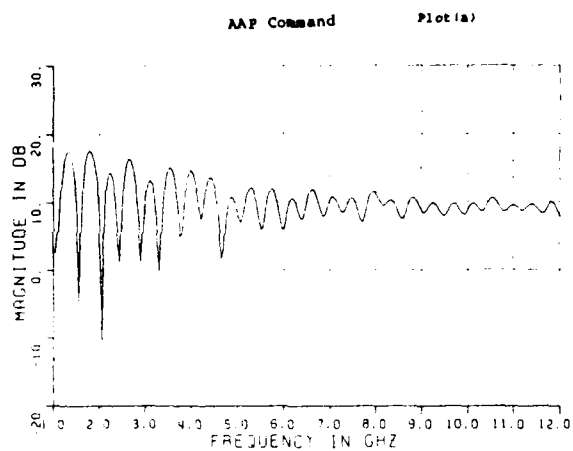
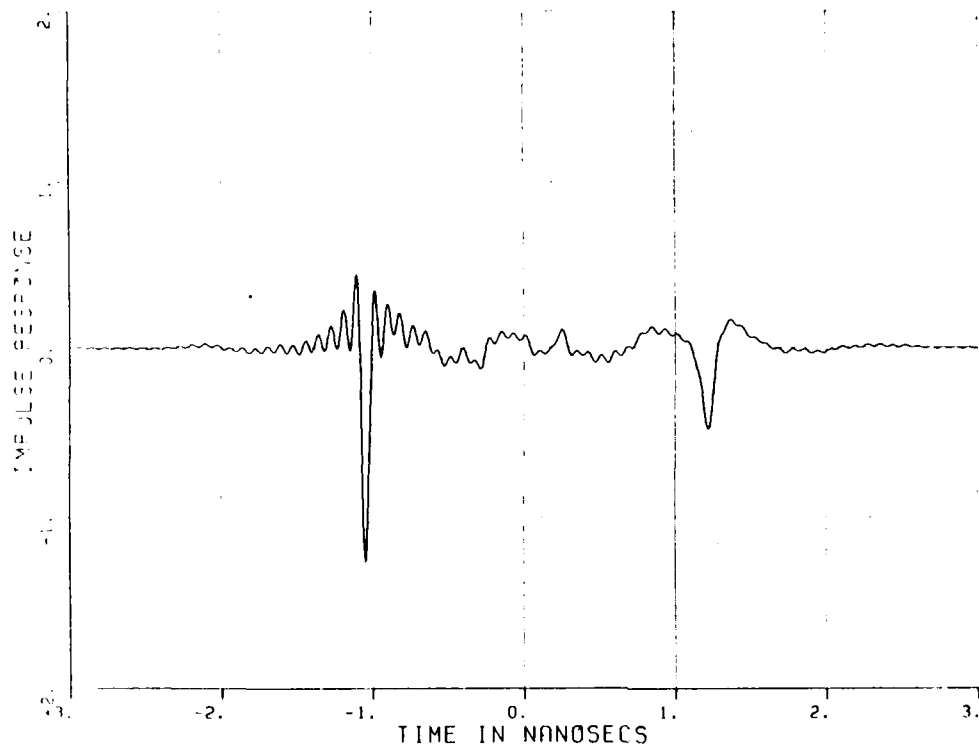
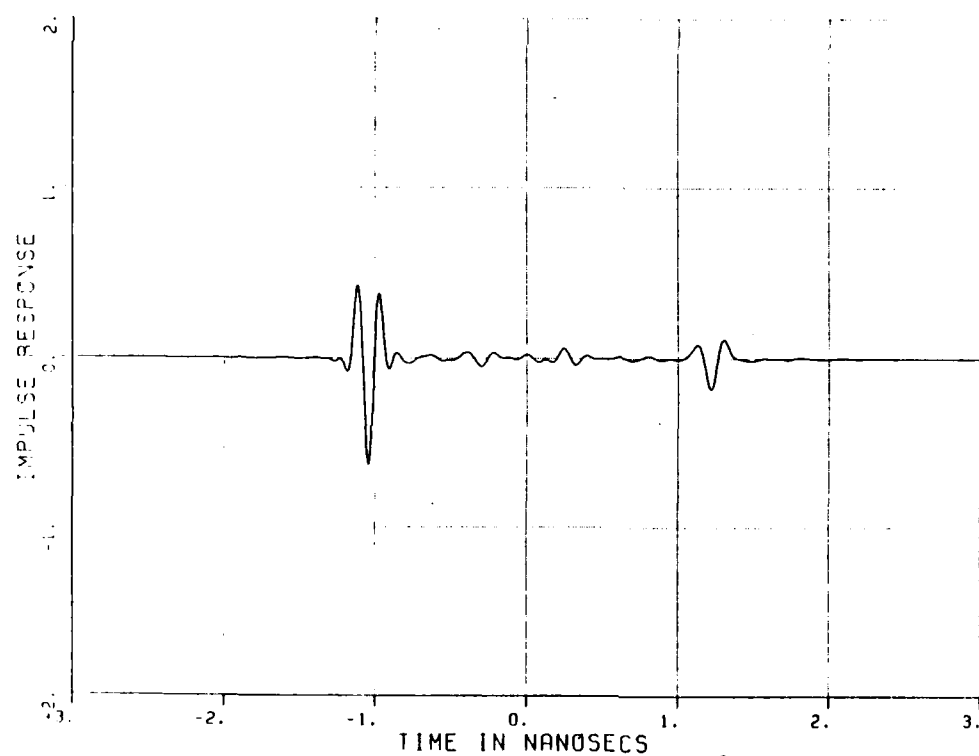


Figure 2.2-5 Ftran Command Illustration

LARGE ELLIPSOID  
 FLAT UP : 0 DEG TILT  
 NI 221 FF= 1000 IN= 50    AA = 0    POL = HH LINEAR



Plot (b) repeated



Plot (g)

WIN - IFT - RPL Command Sequence

Figure 2.2-6 Ftran WIN Command Illustration

## 2.3 MODIFIED FTRAN COMMANDS

The modified version of FTRAN, called FTRAN\_DB, includes the capability of accessing a frequency formatted data base file and calculating circular polarizations and elliptical polarization parameters.

The additional modified FTRAN commands, shown in Figure 2.3-1, are set apart from the original FTRAN commands and flagged with the message " DATA BASE FILES ONLY ".

```
*****  
  
POL : VECTOR PLOT OF THE AMPLITUDE AND PHASE DATA  
EXI : TERMINATE THIS PROGRAM SESSION  
  
MODIFIED FTRAN COMMANDS      ( DATA BASE FILES ONLY )  
  
LDB : LOADS A DATA BASE ASPECT - VV, HH, VH  COMPONENTS  
VVP : SPECIFIES " VV " LINEAR POLARIZATION FOR PROCESSING  
HHP : SPECIFIES " HH " LINEAR POLARIZATION FOR PROCESSING  
VHP : SPECIFIES " VH " LINEAR POLARIZATION FOR PROCESSING  
RCP : SPECIFIES " RR " CIRCULAR POLARIZATION FOR PROCESSING  
LCP : SPECIFIES " LL " CIRCULAR POLARIZATION FOR PROCESSING  
XCP : SPECIFIES " LR " CIRCULAR POLARIZATION FOR PROCESSING  
RPC : SPECIFIES & PLOTS " RCP-XMIT " POLARIZATION PARAMETERS  
LPC : SPECIFIES & PLOTS " LCP-XMIT " POLARIZATION PARAMETERS  
DPA : REMOVES POSITIONAL ERRORS AND RE-CAL*S CP COMPONENTS  
PUT : STORES PROCESSED DATA AND RE-CAL*S CP COMPONENTS
```

Figure 2.3-1 Additional menu commands

```
*****  
  
A detailed explanation of the workings of the modified FTRAN commands  
are discussed in Sections 2.3.1 through 2.3.6.
```

### 2.3.1 LDB command

The LDB command loads three data records of a data base file into the FTRAN\_DB run-time program memory.

On execution of the LDB command the user is prompted for the name of the data base and then the aspect angle. Next, the data base file is opened and the three linear polarization types ( HH, VV, and VH ) at the specified aspect angle are retrieved. If all three linear polarizations exist, a common frequency bandwidth is found between them and the circular polarizations ( RCP, LCP, and XCP ) are calculated over this common bandwidth. If data does not exist at one or more of the linear polarization types, the circular polarization types are not calculated; a message is displayed informing the user of this condition.

The co-polarized circular components are denoted by RCP, for transmit right circular receive right circular, and LCP, for transmit left circular receive left circular. The cross-polarized circular component XCP denotes either transmit right circular and receive left circular or transmit left circular and receive right circular.

The algorithms used in calculation of the circular polarization types are the following:

For RCP

$$RCP = ( HH - VV ) / 2.0 - j ( HV )$$

For LCP

$$LCP = ( HH - VV ) / 2.0 + j ( HV )$$

For XCP

$$XCP = ( HH + VV ) / 2.0$$

After the LDB command is successfully executed, a three-line information block is displayed. On the first line, the accessed data base name is displayed, on the second line, the first comment line of the data base file is displayed. On the third line, the number of data points, the start frequency, and frequency increment of the common frequency bandwidth are displayed. Also on the third line, the aspect angle, and polarization type are displayed.

When the LDB command is first executed the polarization type is displayed as "NOT SPECIFIED", this indicates that no data is stored in the processing array called AMP and PHASE. To store data in the processing arrays, other modified FTRAN commands must be executed ( see Sections 2.3.2 - 2.3.3 ).

The information block is formatted as shown in Figure 2.3.1-1 where NL denotes the number of data points, FF denotes the first frequency, IN denotes the frequency increment, AA denotes for the aspect angle requested, and POL denotes the polarization type specified.

\*\*\*\*\*

```
DATA BASE NAME
FIRST COMMENT LINE OF DATA BASE FILE
NL 221 FF= 1000 IN= 50  AA = 20  POL = NOT SPECIFIED
```

Figure 2.3.1-1 LDB informatin block

\*\*\*\*\*

Additional calls to LDB routine will allow the user to default to the last data base called by entering a "D" ( for default ) into the file name prompt.

### 2.3.2 VVP command

The VVP ( transmit vertical receive vertical polarization ) command loads the co-polarized vertical polarized data string into the FTRAN\_DB processing array buffers called AMP( \* ) and PHASE( \* ). These two arrays provide access to all the original FTRAN commands such as IFT, FFT, APP, etc. After the VVP command has been successfully executed, the information block is again displayed, but with the polarization type changed to VVP as shown in Figure 2.3.2-1.

\*\*\*\*\*

```
DATA BASE NAME
FIRST COMMENT LINE OF DATA BASE FILE
NL 221 FF= 1000 IN= 50  AA = 20  POL = VVP
```

Figure 2.3.2-1 VVP informatin block

\*\*\*\*\*

### 2.3.3 HHP, VHP, RCP, LCP, XCP commands

The commands HHP, VHP, RCP, LCP, and XCP similar to the VVP command, load the corresponding data string into the AMP and PHASE processing data arrays. After any one of these specifying commands are executed, the information block is displayed with the polarization type updated accordingly. If any requested components do not exist, the user informed that the polarization is unavailable for processing and the last data string specified is still stored in the processing arrays. The current data string stored in the processing arrays can be checked with the LAB command, this command will displays the information block.

### 2.3.4 RPC and LPC command

The RPC and LPC commands enables the user to plot the elliptical polarization radar return from either right and left handed transmitted circular polarization, respectively. After an RCP or LCP command is executed, a sub-menu of commands is displayed as shown in Figure 2.3.4-1. This allows the user to select either a rectangular or POINCARE' sphere [6] projection plotting format.

```
*****  
  
POLARIZATION PARAMETER PLOTS  
  
POINCARE sphere projection  
RECTANGULAR plots  
EXIT plots '  
  
ENTER TYPE ->
```

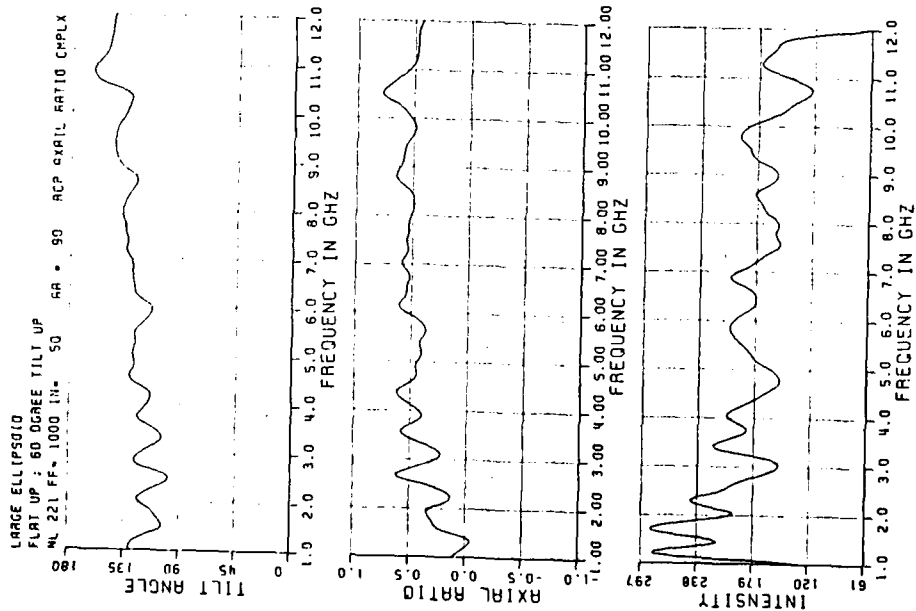
Figure 2.3.4-1 Plot menu

\*\*\*\*\*

Wave polarization can be described as a polarization ellipse [7] and decomposed into components of axial ratio ( ratio of minor and major axis of the polarization ellipse ), tilt angle of ellipse ( angular rotation of ellipse from a reference axis ), and the wave intensity ( a measure of the area contained in the ellipse ).

The rectangular plots and POINCARE' plane sphere projections are two ways of displaying this information. Each method provides the user with a different perspective of the data string. Figures 2.3.4-2 & 2.3.4-3 illustrate the two methods of display.

In Figure 2.3.4-2, the elliptically polarized radar return is displayed in rectangular format. The figure consists of three rectangular plots describing the decomposed elliptical polarization parameters. The top plot, plot(a), displays the tilt angle of the polarization ellipse versus frequency. Zero degrees on the tilt angle axis represents a vertical orientation of the polarization ellipse, and ninety degrees represents a horizontal orientation. The middle plot, plot(b), displays the axial ratio of the polarization ellipse versus frequency ranging between one and minus one. Data on the positive side of the axial ratio plot represents right-hand elliptical polarization while data on the negative side represents left-hand elliptical polarization. Data points at one and minus one represent right and left circular polarization, respectively, while data points at zero represent linear polarization. The last plot, plot(c), displays the wave intensity of the the radar return versus frequency, and represents a measure of the power contained in the polarization ellipse. The ordinate axis for the wave intensity is automatically scaled according to the maximum and minimum values of the plotted data string.



Polarization parameters

Figure 2.3.4-2 ( rectangular format )

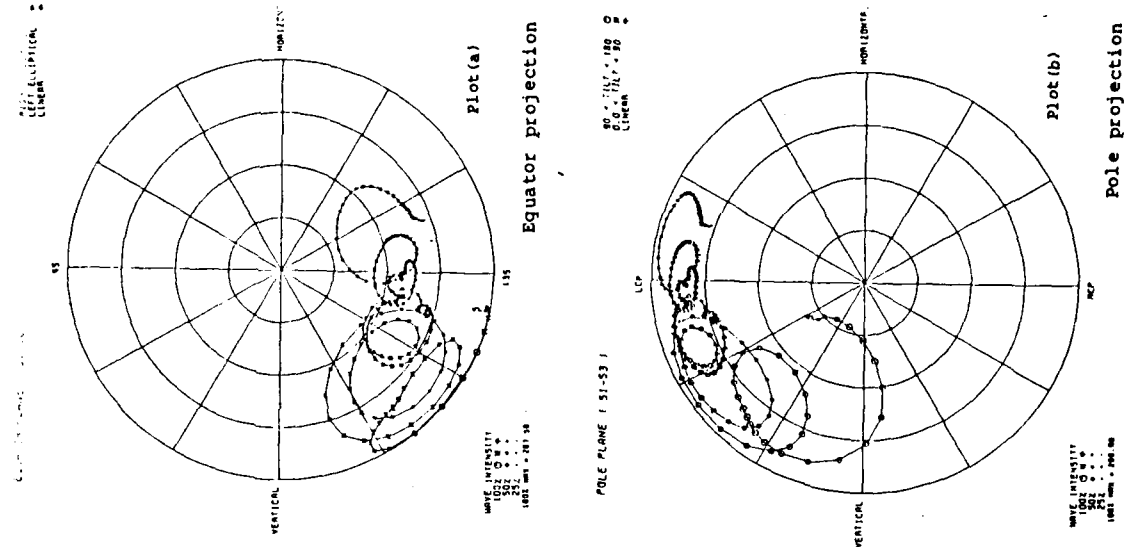


Figure 2.3.4-3 ( Poincare' format )

Figure 2.3.4-3 illustrates the second display mode: plane projections of the Poincare' sphere. Two plane projections of the Poincare' sphere are available to the user when the Poincare' plot is requested. They are the equator plane, as shown in plot(a), or the pole plane as shown in plot(b). The three elliptical polarization parameters: tilt angle, axial ratio, and wave intensity, are all described in the single Poincare' plane projection.

For the equator plane projection, the degree of ellipticity ( ie. axial ratio of the polarization ellipse ) is described by the distance from the center of the circular grid. The center of the grid represents circular polarization and the poles of the polarization sphere, while the outer circle of the grid represents linear polarization and the equator of the sphere. The tilt angle of the polarization ellipse is described by the angular position on the plane projection. Four tilt angle positions are indicated on the plot for reference. They are: horizontal ( ie. zero or one-hundred-eighty degrees ), 45 ( or 225 ), vertical ( 90 or 270 ), and 135 ( or 315 ). The sense of polarization ( ie. right or left elliptical polarization ) is indicated by the symbols "circle", for right elliptical ( lower hemisphere ), and "star", for left elliptical ( upper hemisphere). Additionally, a "arrow" symbol is provided to indicate linear polarization. The wave intensity, a measure of Poincare' sphere radius, is normalized by maximum value of the intensity data string and is displayed by the size of the plotted symbols. A table in the lower left area of the plot identifies the maximum value of wave intensity and corresponding symbol sizes for one hundred, fifty, and twenty-five percent of the maximum value.

A pole plane projection for the same data string, as shown in the equator plane projection, is shown in plot(b). Here the *planar projection of the sphere* is the pole plane containing the horizontal and vertical equator locations. The pole plane projection redefines the plotting symbols to indicate polarization locations from the front or rear hemisphere. Data points from the rear hemisphere are indicated by the "star" symbol, and represent polarization ellipses having a tilt angle between zero and ninety degrees. Data points from the front hemisphere are indicated by the "circle" symbol, and represent polarization ellipses having a tilt angle between ninety and one hundred eighty degrees. And data points that lie on the equator, as in the equator plane plot, represents linear polarization are indicated by the "arrow" symbol.

The start, middle, and final frequencies of the formatted data string are indicated on the plot by the capital letters S, M, and F. The corresponding frequency values for the start and final positions are displayed in the fourth text line of the header. The letters FF represent the first frequency, IN represents the frequency increment, and NL represents the number of lines or points. The numeric values for frequency are in megahertz, and the final frequency can be calculated by:  $FF + ( NL * IN )$ .

Markings in the upper left corner of the plot indicate whether the plot is an equator and pole plane projection. The S1, S2, and S3, markings in parentheses indicate the Stokes parameters used to generate the plot projection.

### 2.3.5 DPA

The DPA command allows the user to offset postional displacements between the HH, VV, and HV linear polarizations and recalculates the circular polarization components RRC, LLC, and RLC. Positional displacements occur between the linear polarizations for many reasons including those listed in Table 2.3.5-1.

\*\*\*\*\*

Rotation of transmitt antenna for orthogonal polarizations  
Measurements for different polarizations taken days apart  
Non-repeatable placement of target and calibration sphere

Table 2.3.5-1 DPA conditions

\*\*\*\*\*

The postional adjustment prompts the user to enter the offsets values, in meters, for each of the linear polarization types. Each time the DPA routine is executed, the original values read from the data base file are altered. Plots illustrating the usage and effect of this command are shown in Figure 2.3.5-1. The plots( a, b, & c ) show time domain plots for the ellipsoidal body at a tilt angle of sixty degree ( see Figure 2.2-4 ) for the polarizations HH, VV, and HV, at an aspect angle of zero degrees. Notice that the minimum impulse response values for the HH, VV, and HV polarizations are located at approximately .52, .47, and .37 nanoseconds , respectively. This minimum location, in each case, represents the the same physical location on the target's body. With the DPA command the time domain plots( a, b, & c ) can be adjusted to the plots of ( d, e, & f ) with HH, VV, and VH, offset of -.078, -.070, and -.055 meters, respectively. The alinement correction can make a substantial difference in the elliptical polarization responses as illustrated by the Poincare' plots in Figure 2.3.5-2. Plot(a) shows the ellipsoid data of Figure 2.3.5-1 plots( a, b, & c ) plotted on the Poincare' sphere equator projection, versus plot(b), which shows the adjusted data of Figure 2.3.5-1 plots( d, e, & f ) plotted with the same Poincare' projection. Thus, care must be taken to ensure the proper alinement of the data strings HH, VV, and HV, before plotting the circular polarizations RCP, LCP, XCP, and circular polarization components RPC, AND LPC.

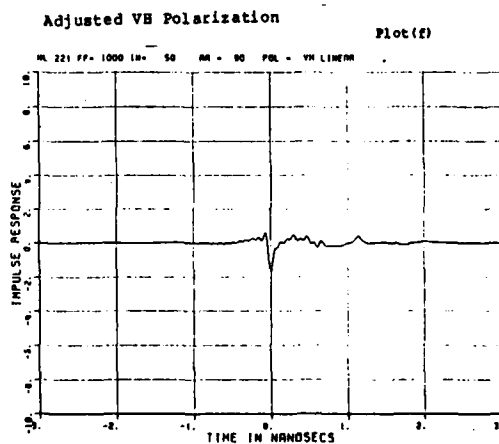
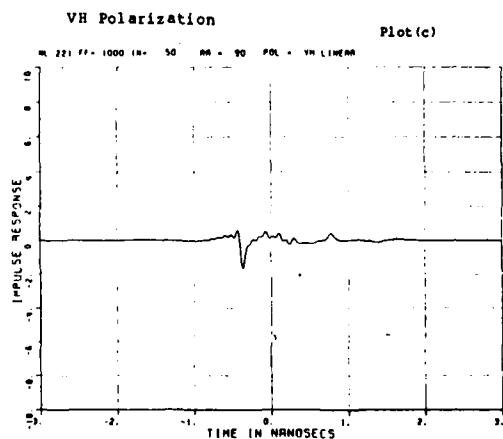
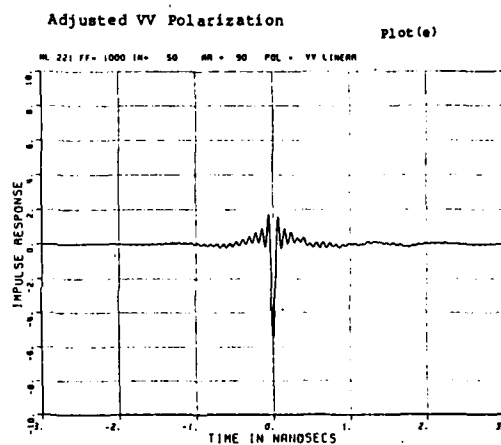
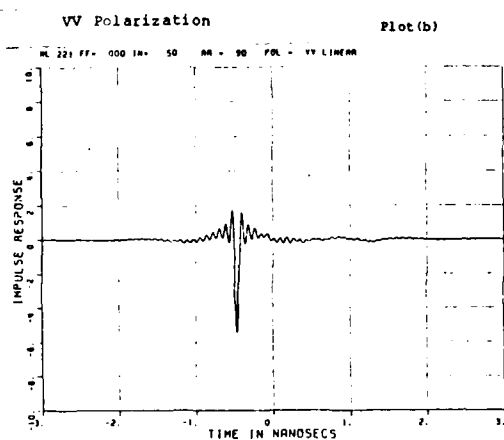
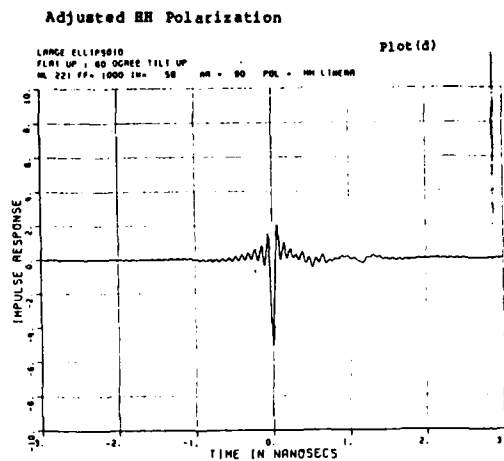
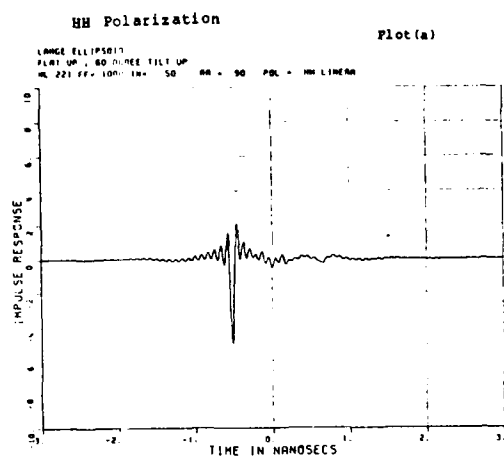
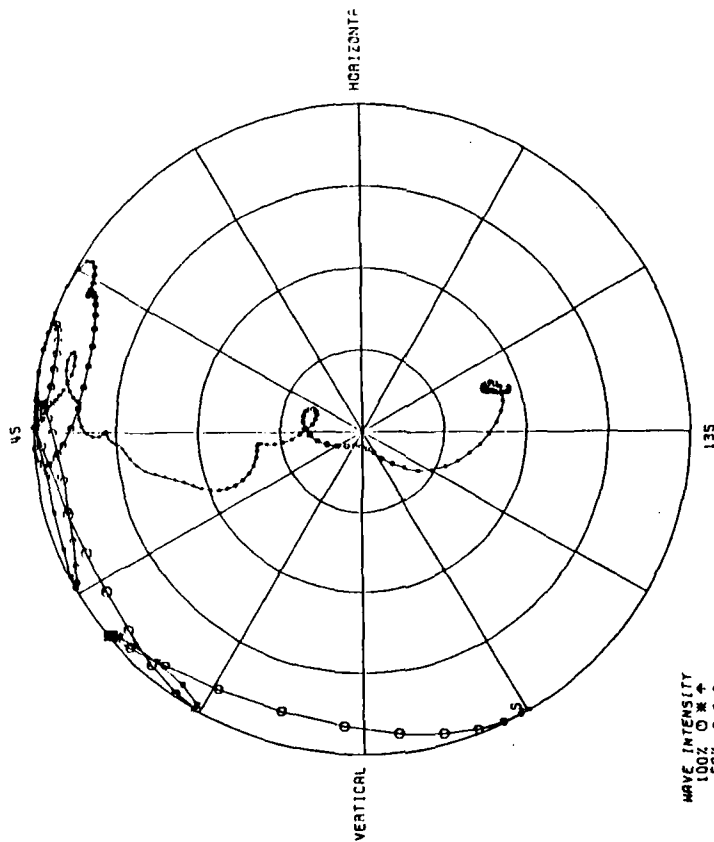


Figure 2.3.5-1 DPA Command Illustration

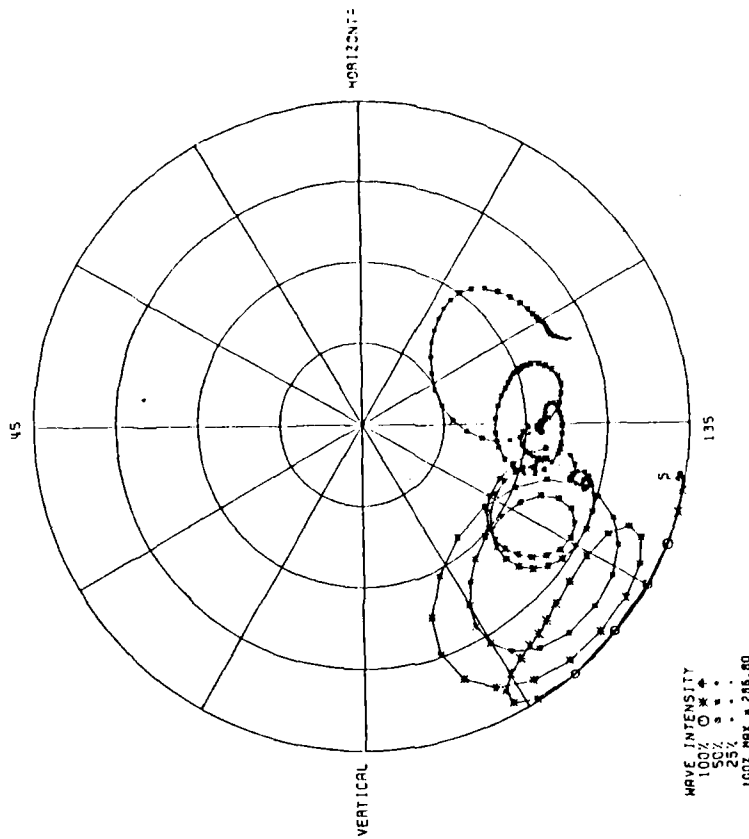
LARGE ELLIPSOID  
FLAT UP: 60 DEGREE TILT UP  
NL 221 FF= 1000 IN= 50  
AA = 90 RCP-XMIT POINCARÉ  
EQUATOR PLANE ( S1-S2 )  
RIGHT ELLIPTICAL ○  
LEFT ELLIPTICAL \*  
LINEAR \*



Plot (a)

Non-Aligned Polarizations

LARGE ELLIPSOID  
FLAT UP: 60 DEGREE TILT UP  
NL 221 FF= 1000 IN= 50  
AA = 90 RCP-XMIT POINCARÉ  
EQUATOR PLANE ( S1-S2 )  
RIGHT ELLIPTICAL ○  
LEFT ELLIPTICAL \*  
LINEAR \*



Plot (b)

Aligned Polarizations

Aligned and Non-Aligned polarizations plotted on a Poincaré' plane projection.

Figure 2.3.5-2

### 2.3.6 PUT

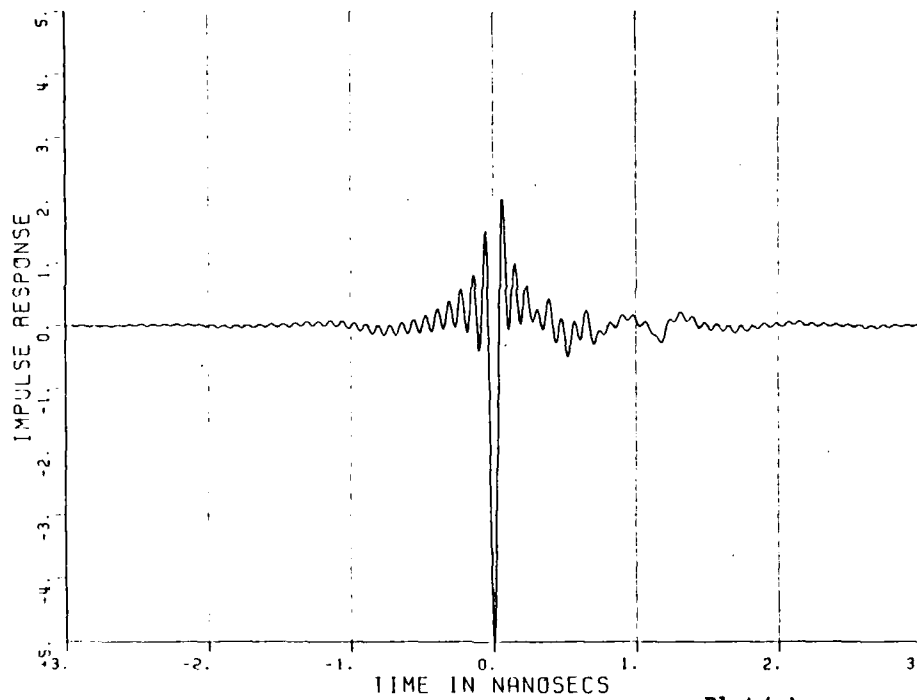
The PUT command allows the user to recalculate the circular polarizations and elliptical polarization parameters after the processing ( ie. IFT, GAT, FFT, etc.. ) of any linear polarization. If only the circular polarizations are processed, only the elliptical polarization parameters are recalculated.

The usage of this command and some of the FTRAN\_DB data string processing commands are presented here in a series of figures. Again, data from the sixty degree tilted ellipsoid body ( see Figure 2.2-4 ) is used to demonstrate the commands. After the LDB command has been executed to load the data strings in to executable memory from a data base, the DPA command is used to remove the positional errors in the three linear polarizations, as illustrated in the DPA command section. Once the positional errors have been removed, the HHP command is executed to load the HH linear polarized component into the processing array buffer. Next, the IFT command is executed to transform the frequency domain data into time domain data. Once the transformation is completed, the GAT command is used to separate the predominate specular return from the creeping wave and the other scattering mechanisms. The data represented in Figure 2.3.6-1 shows the results of this procedure for the HH linear polarization component. The time gate was set from minus one-half to plus one-half nanoseconds. Next, the FFT command was executed to transform the time formatted data back into the frequency format shown in Figure 2.3.6-2. Finally the PUT command is executed, and new circular components and elliptical polarization parameters are calculated.

To achieve meaningful circular polarizations and elliptical polarization parameters, the same procedures that processed the HH linear polarization must also be repeated for the VV and VH polarizations.

Figure 2.3.6-3 shows the Poincare' equator plane projections after the above procedures are accomplished. Plot(a) shows that the specular return begins linearly polarized, at wavelengths comparable to the size of the ellipsoid, at a tilt angle of sixty degrees from the horizontal reference. As expected, the specular return gradually approaches towards circular polarization along the elliptical tilt angle of sixty degrees as the frequency increases. Using the same technique, plot(b) shows the Poincare' equator plane projection of the creeping wave and other scattering mechanisms contained in the time gate set from minus one-half to two nanoseconds.

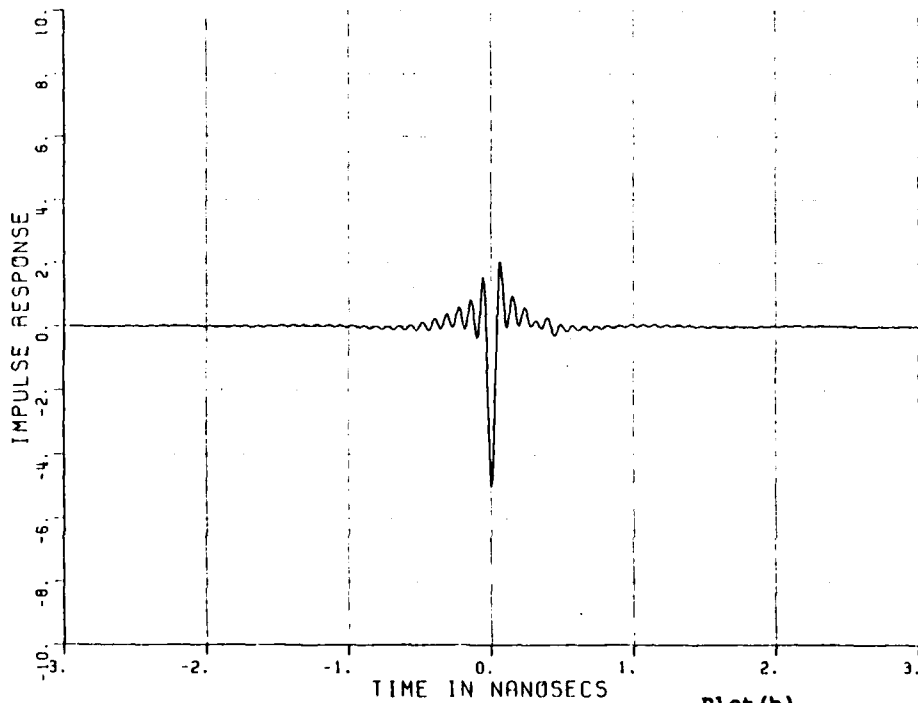
LARGE ELLIPSOID  
 FLAT UP : 60 DEGREE TILT UP  
 NL 221 FF= 1000 IN= 50 AA = 90 POL = HH LINEAR



Plot (a)

HH Polarization " Time Domain response "

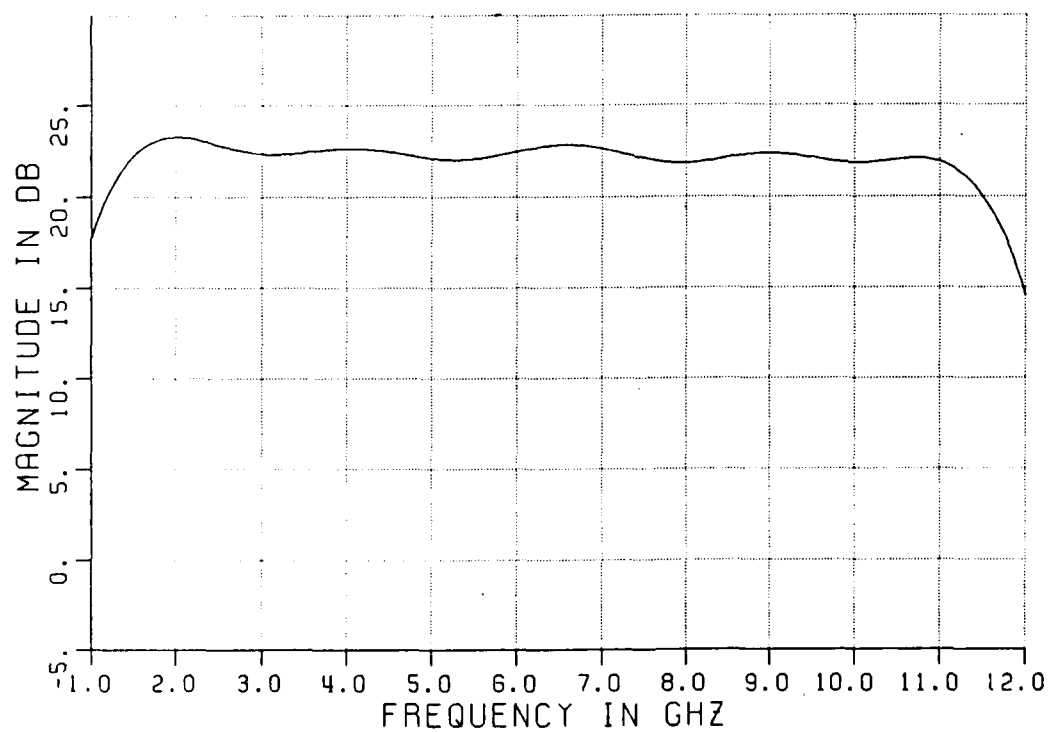
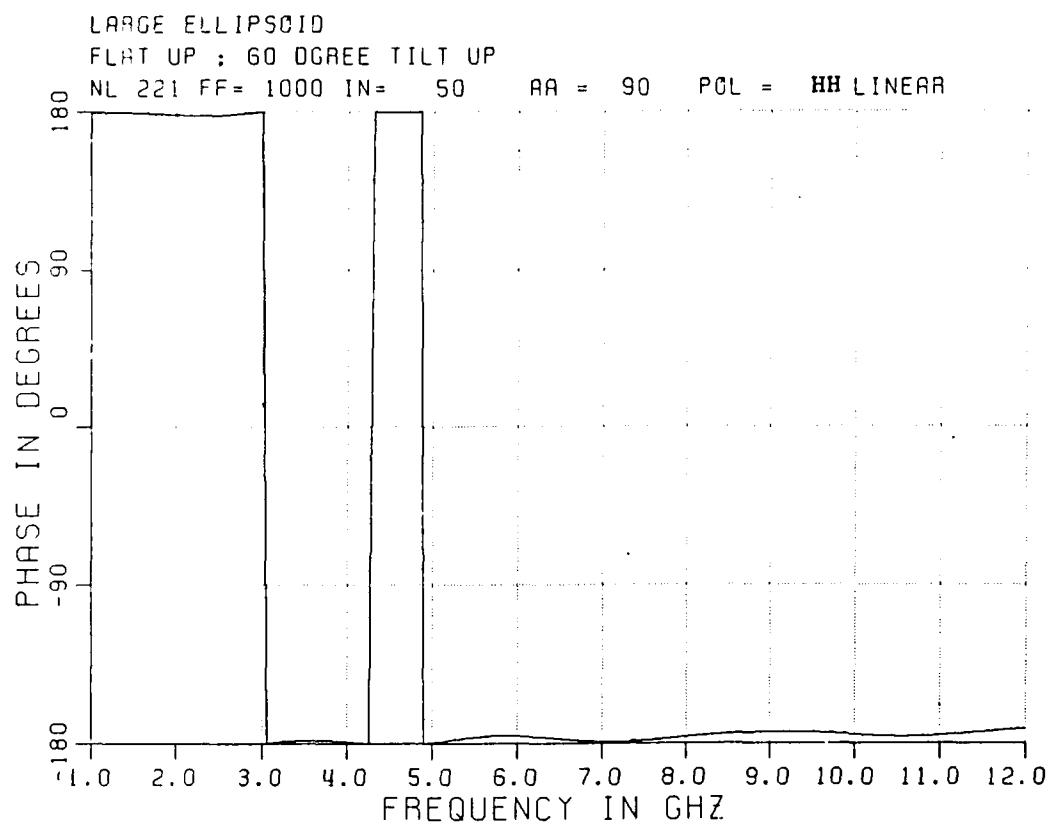
LARGE ELLIPSOID  
 FLAT UP : 60 DEGREE TILT UP  
 NL 221 FF= 1000 IN= 50 AA = 90 POL = HH LINEAR



Plot (b)

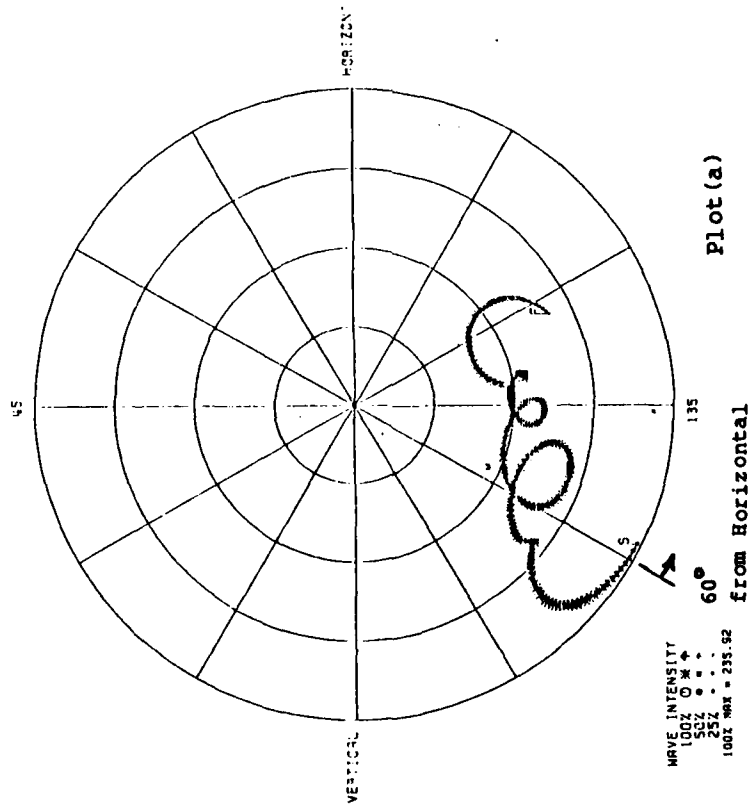
HH Polarization " Gated Time Domain response "

Figure 2.3.6-1 Data Processing for PUT Command Illustration



HHP - AAP Command Sequence after PUT Command Execution

Figure 2.3.6-2 Result of PUT Command

[illegible]

## SECTION 3

### 3.1 PROGRAM: RADAR SYSTEM SIMULATION AND EVALUATION ( RSSE ) PROGRAM

The RSSE program was designed to simulate a variety of radar systems, and evaluate their ability to classify RCS measurements for practical systems.

The RSSE program represents the third generation of simulation programs written at the ESL. This latest version incorporates a modular programming style which allows for expansion of new radar types, identification routines, and noise models. Other new features included in this new program are run time allocated ( dynamic ) data arrays, and DATA BASE file usage.

### 3.2 MENU LISTING

The RSSE program has several menus of operation, the main menu as shown in Figure 3.2-1 consists of eleven commands.

\*\*\*\*\*

#### Radar System Simulation and Evaluation (RSSE) Commands :

CREATE a data matrix.  
CHANGE features of the data matrix.  
DISPLAY the features of the data matrix.  
EXIT from the program.  
HELP messages.  
IDENTIFICATION routines.  
MAP the data matrix.  
MENU of commands.  
PLOT package setup.  
\$ " any VAX/VMS DCL command ".

All commands may be abbreviated  
Answer YES or NO for all questions. The default is YES  
unless stated otherwise.

Figure 3.2-1 Main menu

\*\*\*\*\*

### 3.2.1 MENU SUMMARY

A brief introduction to the main menu commands are as follows:

**CREATE** : Creates a data matrix from requested DATA BASE files, frequencies, aspect angles, and polarization types.

**CHANGE** : Allows the user to change the data matrix by requesting new DATA BASE files, frequencies, aspects angles, or polarization types.

**DISPLAY**: Allows the user to display the parameters entered in the CREATE or CHANGE command.

**EXIT** : Exits the program and returns the user to VAX/VMS operation.

**HELP** : Helps the user develop proper execution procedures and corrective measures for program error messages.

**IDENTIFICATION** : Invokes a sub program that is menu driven to perform; the generation of test and catalog subsets, the execution of different identification algorithms, and display formats to summarize the results.

**MAP** : Shows the user the data strings that are read into the data matrix and assigns an identification number to each string for one method of subset generation.

**PLOT** : Selects the plotting devices for the ESL plot package.

**\$ " DCL COMMAND "** : Allows the user to enter a VAX/VMS DCL command for execution while the program is running.

A detailed discussion of the top level RSSE commands is given in the following sections.

### 3.2.1.1 CREATE

The CREATE command creates a data matrix from the requested data base records ( see Section 1 ). When the CREATE command is executed, the user is first prompted to enter an integer value for the number of data bases to be read. For each data base, the file name, scale factor, and elevation angle are entered as follows :

```
FOR DATA BASE # 1
ENTER NAME -> TARGET_2.DAT
ENTER SCALE FACTOR -> 20.0
ENTER VALUE OF ELEVATION ANGLE -> 10
```

```
FOR DATA BASE # 2
ENTER NAME -> TARGET_1.DAT
ENTER SCALE FACTOR -> 10.0
ENTER VALUE OF ELEVATION ANGLE -> 0
```

Etc...

The file name is entered as a character string with a maximum length of sixty characters. The scale factor is entered as a floating point number and must be between the limits of one and five-thousand. Finally, the elevation angle is entered as an integer value between the limits of zero one and three-hundred-sixty degrees. All entered values throughout the RSSE program are processed through a checking routine to ensure that the values that have been entered are within the preset limits.

Presently, only frequency formatted data bases can be processed by the RSSE program ( ie. data bases where the record's data strings are indexed by frequency at a single azimuth angle and polarization type ).

Next, the user is prompted to enter an integer value for the number of azimuth angles to be read. After the azimuth angles values have been entered, an integer number of polarization types, six maximum, is entered. While only three linear types of polarizations are available in a data base ( ie. HH, VV, and VH ), the three circular polarizations types RRC, LLC, and RLC, can be calculated if the three linear polarizations at the specified azimuth angles exist ( see Section 2.3.1 ). If the maximum number is not selected, the polarization types are then entered as character strings, shown in Figure 3.2.1.1-1, as follows:

```
FOR POLARIZATION # 1
ENTER THE POLARIZATION TYPE -> VVP
```

```
FOR POLARIZATION # 2
ENTER THE POLARIZATION TYPE -> RRC
```

Etc...

The first character represents the transmitted polarization the second character represents the received polarization. When the two characters are the same, as in HHP, the radar system is said to be co-polarized. When the two characters are different, as in VHP, the radar system is said to be cross-polarized.

\*\*\*\*\*

The polarization types are :

HHP horizontal - horizontal linear  
VVP vertical - vertical linear  
VHP vertical - horizontal linear  
RRC right - right circular  
LLC left - left circular  
RLC right - left circular

Figure 3.2.1.1-1 Polarization types

\*\*\*\*\*

Finally, the user is prompted for the scaled frequency range start, and stop values, and the number of frequency points. The start and stop scaled frequency values are entered as floating point numbers, and the number of frequencies are entered as an integer.

After the prompts for creating the data matrix have been completed, a summary of the entered prompts is displayed for user verification. If an error exists in the display summary, the user can request a change in the data matrix before the data acquisition routine is executed ( see Section 3.2.1.2 ). If no errors exists in the display summary, the user defaults on the change parameter prompt and data acquisition begins. After data acquisition is completed, the user is informed as to how many items were not read into the data matrix.

The data acquisition routine uses run time ( dynamic ) memory allocation for the data matrix elements. If the data matrix is changed or recreated, the existing data matrix is deallocated and new memory space is allocated to accomodate the new data matrix size. During the data acquisition routine, the amplitude and phase data are converted from power quantities to voltage quantities, changed to complex form, scaled by the target's scale factor, and additionally scaled by a factor of one-hundred. The additional scaling ( ie. the one-hundred factor ), changes the data base quantities from centi-meters to meters.

An example of the data matrix display summary is shown in Figure 3.2.1.1-2. A titled hardcopy of the display summary is available if the hardcopy prompt is set.

\*\*\*\*\*

## 5 TARGETS

TARGET INDEX # 1 -> PLANE\_1

ELEVATION ANGLE = 0  
SCALE FACTOR = 200.00

TARGET INDEX # 2 -> PLANE\_2

ELEVATION ANGLE = 0  
SCALE FACTOR = 200.00

TARGET INDEX # 3 -> PLANE\_3

ELEVATION ANGLE = 150  
SCALE FACTOR = 150.00

TARGET INDEX # 4 -> PLANE\_4

ELEVATION ANGLE = 0  
SCALE FACTOR = 200.00

TARGET INDEX # 5 -> PLANE\_5

ELEVATION ANGLE = 0  
SCALE FACTOR = 200.00

---

## 3 AZIMUTH ANGLES

ANGLE INDEX # 1 -> 0  
ANGLE INDEX # 2 -> 45  
ANGLE INDEX # 3 -> 90

---

## 3 POLARIZATION TYPES

POLARIZATION INDEX # 1 -> HHP  
POLARIZATION INDEX # 2 -> VVP  
POLARIZATION INDEX # 3 -> RRC

---

START FREQUENCY -> 8.00 MHz  
STOP FREQUENCY -> 58.00 MHz  
FREQUENCY INCREMENT -> 10.00 MHz

Figure 3211-2 Data matrix display summary

\*\*\*\*\*

### 3.2.1.2 CHANGE

The CHANGE command is available to the user after a CREATE command has been executed.

If the CHANGE command is requested, a sub-menu, as shown in Figure 3.2.1.2-1 is displayed. This sub-menu allows the user to change a section of the data matrix acquisition parameters. Once the CHANGE command has been executed the data matrix display summary ( Figure 3.2.1.1-2 ) appears updated with the new parameters. After the first CHANGE command has been completed, and the display summary displayed, the user is prompted for additional changes. If the user defaults on the additional changes, the data acquisition routine begins with the new data matrix parameter.

\*\*\*\*\*

Targets  
Azimuth angles  
Polarizations  
Frequencies

Enter Feature to change ->

Figure 3.2.1.2-1 Change parameters sub-menu

\*\*\*\*\*

### 3.2.1.3 DISPLAY

The DISPLAY command allows the user to display the current data acquisition parameters as shown in Figure 3.2.1.2-1. The display routine allows the user to request a hardcopy of the display; a sixty character label can be added for documentation.

#### 3.2.1.4 HELP

The HELP command provides the user with information pertaining to the top level commands, error messages, and additional software that uses the data base format. The HELP command is supported by the DEC VAX/VMS V4.0 system software and allows the help routine to be set up in a multi level structure ( ie. the help topics branch down to subtopics ) [4], [5]. Figure 3.2.1.4-1 shows the major help topics currently available to the user, and an example of a help message display.

\*\*\*\*\*

Information available:

AUTHOR	CREATE	CHANGE	DISPLAY	ERRORS	MAP
IDENTIFICATION		MENU	PLOT	START_UP	\$DCL

Topic? IDENTIFICATION

Invokes a sub program that is menu driven to perform ; the generation of test and catalog subsets, the execution of different identification algorithms, and different display formats to summarize the results.

Additional information available:

DISPLAY	GENERATE	NEAREST
---------	----------	---------

Sub Topic?

Figure 3.2.1.4-1 Main RSSE Help display

\*\*\*\*\*

### 3.2.1.5 IDENTIFICATION

The IDENTIFICATION command transfers the user to the identification menu format. This new menu, shown in Figure 3.2.1.5-1, contains seven commands that allow the user to do target identification.

At present, only the single nearest neighbor algorithm [8] is available for feature identification. Future modifications of the RSSE will incorporate additional techniques such as correlation, adaptive, and the k-nearest neighbor, for feature identification.

\*\*\*\*\*

#### IDENTIFICATION ROUTINE COMMANDS

GENERATE a test & catalog set. ( ie. subsets of the MAP )  
NEAREST neighbor technique to identify test set targets.  
DISPLAY results  
HELP messages  
EXIT the RSSE program.  
QUIT identification routines.  
\$ " any VAX/VMS DCL command ".

All commands may be abbreviated  
Answer YES or NO for all questions. The default is YES  
unless stated otherwise.

SELECT AN OPTION FOR EXECUTION - >

Figure 3.2.1.5-1 Identification Menu

\*\*\*\*\*

### 3.2.1.5 IDENTIFICATION MENU COMMANDS

#### 3.2.1.5.1 GENERATE

The GENERATE command allows the user to create two subsets from the data matrix. The two subsets, called the test set and catalog set, and are queued once a radar type has been selected. Three radar types are available ( see Figure 3.2.1.5.1-1 ), and are derived from the six polarization types listed in Figure 3.2.1.1-1. The ARBITRARY radar type allows the user to simulate radar systems of any of the six polarization types, while the DIVERSE radar types, LINEAR and CIRCULAR, allows the user to simulate "post-detection" linear and non-linear combinations of the six polarization types.

After the selection of a radar type has been determined, the user is prompted to choose elements for the test and catalog subsets. The first subset of the data to be created is the test set. The test set, in identification schemes, denotes the set of data that is to be corrupted with noise and then identified as a simulated radar return. The catalog set, denotes the set of data that is to be used to identify the elements in the test set.

The ARBITRARY radar type allows the user to create the two subsets with any valid elements from the map listing ( see Figure 3.2.1.6-1 ). Five index file keys enable the user to create the arbitrary radar subsets by specifying either the ID number key ( see Section 3.2.1.6 ), target name key, azimuth angle key, elevation angle key, or polarization type key. In each case, the user can select individual elements or a range of elements by specifying quantities associated with the chosen key. For example, if the azimuth angles of 0, 15, 30, 45, 50, and 90, degrees are in the data matrix and the user desires angles between the limits of 0 and 45 in the test set, the user would choose the azimuth key type and select the range option for angles between these limits. The test subset would then be created with all the elements in the map listing containing the azimuth angles 0, 15, 30, and 45 degrees. With the target and polarization key types, the range selection option works on an alpha-numeric ordering. If any element in the map listing is denoted with an asterisk, it is invalid and excluded from the subset generation.

The LINEAR DIVERSE radar types allows the user to create the two subsets with combinations of the linear polarization types HH, VV, and VH. The HH, VV, and VH combinations consists of a complex sum of the three components ( ie.  $HH + VV + VH$  ), a concatenation of the three components, and ratio combinations of the components (ie.  $HH/VV$ , or  $HH/VH$ , or  $VV/HH$ , or  $VV/VH$ , etc.. ). The CIRCULAR DIVERSE radar types allows the user to create subsets consisting of various combinations of the circular polarization types RRC, LLC, and RLC. The circular diverse types, similar to the linear diverse types, allows the selection of either a complex sum, or concatenation of circular components. However, instead of a ratio of components, the circular diverse offers the axial ratio of the polarization ellipse [7].

The sub-menus displayed in the RSSE program for the radar type selections are show in Figure 3.2.1.5.1-2 plots( a,b,c ).

\*\*\*\*\*

## RADAR TYPES

ARBITRARY polarization radar ( ie. LINEAR & CP elements )  
LINEAR polarization diverse radar ( ie. HH, VV, VH combinations )  
CIRCULAR polarization diverse radar ( ie. AXIAL RATIO & CP combinations )

ENTER THE TYPE OF RADAR - >

Figure 3.2.1.5.1-1 RSSE radar type menu

\*\*\*\*\*

## ARBITRARY RADAR TYPE CREATE COMMANDS :

ID# key.  
TARGET name key.  
AZIMUTH angle key.  
ELEVATION angle key.  
POLARIZATION type key.

Select a key type to create the set ->

(a) Arbitrary radar types

---

## LINEAR POLARIZATION DIVERSE RADAR TYPES:

COMPLEX sum of linear components.  
CONCATENATION of linear components.  
RATIO combinations of HH, VV, & VH

ENTER POLARIZATION DIVERSE TYPE ->

(a) Linear diverse radar types

---

## CIRCULAR POLARIZATION DIVERSE RADAR TYPES:

COMPLEX sum of circular components.  
CONCATENATION of circular components.  
AXIAL ratio ( right or left ) components.

ENTER POLARIZATION DIVERSE TYPE ->

(c) Circular diverse radar types

---

Figure 3.2.1.5.1-2 RSSE radar types

\*\*\*\*\*

When the test and catalog subsets are created, the average power for each element of the subsets is calculated. This is done by taking the average value of the sum of the squares of the magnitude of the complex voltage samples contained in each subset.

The calculation is made by summing the appropriate polarization types that make up the radar type selected. That is, for example, if two frequencies samples are chosen, the average power calculation for a circular diverse radar type would be:

$$( RRC(1)**2 + LLC(1)**2 + RLC(1)**2 + RRC(2)**2 + LLC(2)**2 + RLC(2)**2 ) / 6.0$$

while, for a linear diverse ratio radar type, say HH/VV, the average power calculation would be:

$$( HHP(1)**2 + VVP(1)**2 + HHP(2)**2 + VVP(2)**2 ) / 4.0 .$$

The average power results are useful when examining the mis-classification percentage tables ( see Section 3.2.1.5.3 ). Approximate signal-to-noise ratios can be determined by comparing the table's noise powers to the average power of the subset elements.

### 3.2.1.5.2 NEAREST

The NEAREST command invokes the 1-nearest neighbor algorithm to perform target identification. The nearest neighbor algorithm provides the user with a Euclidian distance measure between elements of the test set and catalog set. The shortest distance measure between an element of the test set and the members of the catalog set is used to identify the test set element.

In the nearest neighbor routine, the user is prompted for four parameters to define the radar simulation process. These parameters are; noise power range, noise model type, distance type, and the number of experiments. The noise power range, specified in dB-sm, is entered by a start, stop, and increment value. These noise steps are applied to the elements in the test set according to the noise model selected. Currently, only an additive Gaussian noise model is available, this noise model simulates a radar environment with many independent noise sources. Noise models [8] in later versions of the RSSE program, will allow the user to simulate many more types of radar environments.

Corrupting the non-linear diverse radars types with noise, requires that the noise corruption be applied to the six polarizations types HH, VV, VH, RR, LL, and RL before any non-linear combination of polarization types are calculated. For example, if a ratio of HH/VV is requested, the noise steps are applied to the HH and VV polarizations before the ratio operation is executed.

Two distance types are available for obtaining the Euclidian distance measure. They are the "coherent" ( vector ) and "non-coherent" ( magnitude ) distance metrics. The vector distance is based on the two dimensional "complex" subtraction between the samples of the the test set and catalog set samples, while the magnitude distance is a one dimensional "real" subtraction of the magnitudes of the samples in in the test set and catalog set elements. The mathematical representation for the two distance types are:

For vector "coherent" distance

$$\text{Distance}( Ti, Ck ) = \text{sqrt}( \text{sumx}( \text{mag}( Ti(x) - Ck(x) ) ** 2 )$$

For magnitude "non-coherent" distance

$$\text{Distance}( Ti, Ck ) = \text{sqrt}( \text{sumx}( \text{abs\_val}( \text{mag}( Ti(x) ) - \text{mag}( Ck(X) ) ) ** 2 ) )$$

Where "Ti(x)" denotes the complex sample vector of the ith test set element and "Ck(x)" denotes the complex sample vector of the kth catalog set element.

The "number of experiments" prompt, allows the user to enter the number of times the nearest neighbor algorithm is to be executed on elements of the test and catalog sets. Each time the algorithm is executed a random noise seed is injected into the test set corruption routine, thus allowing for a calculation of misclassification statistics.

A flow chart in figure 3.2.1.5.2-1 illustrates the logical progression of commands to execute the NEAREST neighbor algorithm.

\*\*\*\*\*

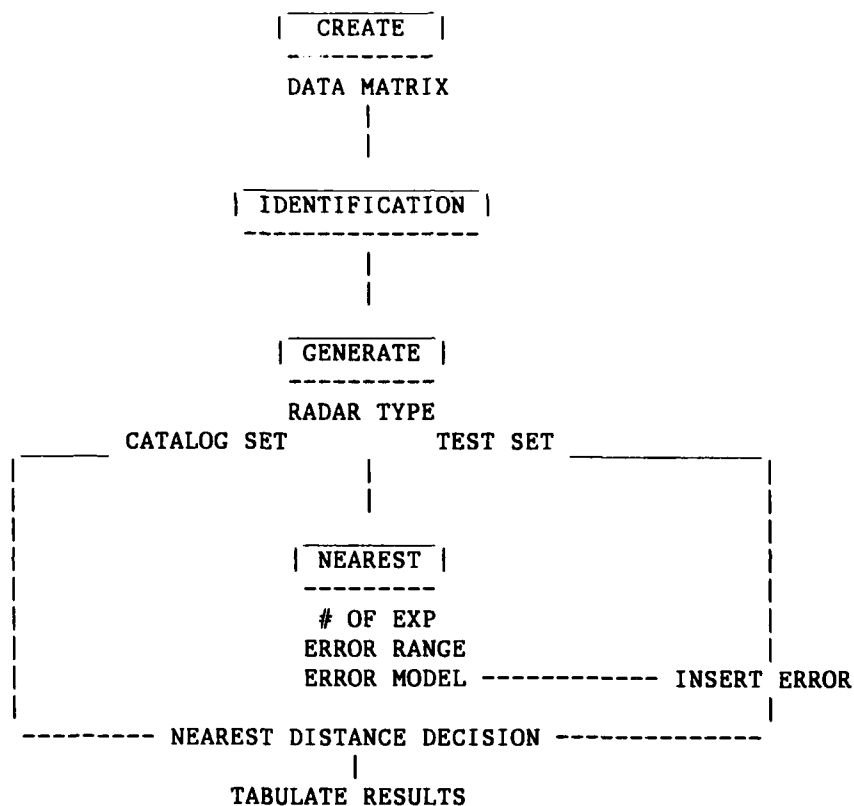


Figure 3.2.1.5.2-1 Procedures to execute the NEAREST command

\*\*\*\*\*

### 3.2.1.5.3 DISPLAY

The DISPLAY command allows the user to display the results of the last classification algorithm executed. The results can be displayed in either a text or tabular style. Both styles display the number of times, out of the total number of experiments, that a test set element was identified as one of the elements in the catalog set.

The tabular format also calculates and displays mis-classification percentages. The mis-classification percentages can be chosen to provide mis-classification statistics based on either the target name, azimuth angle, elevation angle, or polarization type.

The results of the classification algorithms are displayed as a function of the average power of the noise. The display routine allows the user to display any one of the error levels by requesting a page number. A list of page numbers with their corresponding error power is presented in a sub-menu for the user to choose from. A hardcopy of the results can be requested along with the terminal display. The sub-menu command "ALL" allows the user to scroll through all the noise power level pages.

If the tabular display is requested, the first items are a list of the test and catalog elements mapped to a index number. The index numbers allows the tabular display format to maintain a compact matrix style. All information pertaining to the creation of the subsets (ie. target name, azimuth angle, elevation angle, and radar type ) is displayed. The average power of each element in the test and catalog sets is also displayed in this listing.

An example listing of the tabular output of the identification display routine, for a single error power, is shown in figure 3.2.1.5.3-1.

\*\*\*\*\*

Nearest-Neighbor "vector" distance measure:

#### TEST TARGET INDEX MAPPING

INDEX: 1	PLANE_1	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 7.78
INDEX: 2	PLANE_2	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 20.53
INDEX: 3	PLANE_3	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 20.53
INDEX: 4	PLANE_4	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 14.48
INDEX: 5	PLANE_5	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 23.41

#### CATALOG TARGET INDEX MAPPING

INDEX: 1	PLANE_1	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 7.78
INDEX: 2	PLANE_2	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 20.53
INDEX: 3	PLANE_3	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 20.53
INDEX: 4	PLANE_4	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 14.48
INDEX: 5	PLANE_5	AZ = 0 Deg	EL = 0 Deg	RADAR = HHP	AVER_POW = 23.41

Nearest-Neighbor "vector" distance measure:

Classification Table for Noise power = 25.00 DBSM

TT#/CT#	1	2	3	4	5	% MIS-CLASS
1	50	5	11	30	4	50.00
2	8	79	9	1	3	21.00
3	9	6	70	4	11	30.00
4	18	13	5	64	0	36.00
5	3	4	7	0	86	14.00

Average mis-classification percentage : 30.20 %

Mis-classification percentage is based on the test targets name.

Figure 3.2.1.5.3-2 DISPLAY command example

\*\*\*\*\*

#### 3.2.1.5.4 HELP

Similar to the HELP command of Section 3.2.1.4, but providing information pertaining to the identification menu only. Figure 3.2.1.5.4-1 shows the major identification help topics currently available to the user.

\*\*\*\*\*

Information available:

DISPLAY      GENERATE      NEAREST

Figure 3.2.1.5.4-1      Identification HELP routine display

\*\*\*\*\*

#### 3.2.1.5.5 QUIT

The QUIT command allows the user to return to the main RSSE menu.

#### 3.2.1.6 MAP

The MAP command allows the user to view the data entered into the data matrix. The MAP command also assigns an identification number to each element in the data matrix, thus allowing for easier generation of test and catalog sets ( see Section 3.2.1.5.1 ). If the acquisition of any element requested for the data matrix fails in any part of the data acquisition routine, an asterisk is placed beside the corresponding element. Reasons for data acquisition error are listed in Table 3.2.1.6. An example of a map listing for a data matrix consisting of five plane, four azimuth angles, and three polarization types is shown in Figure 3.2.1.6-1. The map listing corresponds to the data matrix display summary list of Figure 3.2.1.1-2.

\*\*\*\*\*

ANGLE OR POLARIZATION TYPE REQUESTED ARE NOT IN THE DATA BASE  
REQUESTED SCALED FREQUENCIES ARE OUTSIDE EXISTING DATA RANGE  
HH, VV, OR VH COMPONENTS MISSING FOR THE CALCULATION OF CIRCULAR  
POLARIZATIONS

Table 3.2.1.6      Data Matrix Error Conditions

\*\*\*\*\*

# MAPPING OF THE DATA BASE

ID#	TARGET	AZ	EL	POL	
1	PLANE_1	0	0	HHP	
2	PLANE_1	15	0	HHP	
3	PLANE_1	45	0	HHP	
4	PLANE_1	0	0	VVP	
5	PLANE_1	15	0	VVP	
6	PLANE_1	45	0	VVP	
7	PLANE_1	0	0	RRC	
8	PLANE_1	15	0	RRC	*
9	PLANE_1	45	0	RRC	
10	PLANE_2	0	0	HHP	
11	PLANE_2	15	0	HHP	
12	PLANE_2	45	0	HHP	
13	PLANE_2	0	0	VVP	
14	PLANE_2	15	0	VVP	
15	PLANE_2	45	0	VVP	
16	PLANE_2	0	0	RRC	
17	PLANE_2	15	0	RRC	
18	PLANE_2	45	0	RRC	
19	PLANE_3	0	0	HHP	
20	PLANE_3	15	0	HHP	
21	PLANE_3	45	0	HHP	
22	PLANE_3	0	0	VVP	
23	PLANE_3	15	0	VVP	
24	PLANE_3	45	0	VVP	
25	PLANE_3	0	0	RRC	
26	PLANE_3	15	0	RRC	
27	PLANE_3	45	0	RRC	
28	PLANE_4	0	0	HHP	
29	PLANE_4	15	0	HHP	
30	PLANE_4	45	0	HHP	
31	PLANE_4	0	0	VVP	
32	PLANE_4	15	0	VVP	
33	PLANE_4	45	0	VVP	
34	PLANE_4	0	0	RRC	
35	PLANE_4	15	0	RRC	
36	PLANE_4	45	0	RRC	
37	PLANE_5	0	0	HHP	
38	PLANE_5	15	0	HHP	*
39	PLANE_5	45	0	HHP	
40	PLANE_5	0	0	VVP	
41	PLANE_5	15	0	VVP	
42	PLANE_5	45	0	VVP	
43	PLANE_5	0	0	RRC	
44	PLANE_5	15	0	RRC	*
45	PLANE_5	45	0	RRC	

NOTE -> \* indicates feature does not exist

Figure 3.2.1.6-1 Illustration of MAP output

\*\*\*\*\*

### 3.2.1.7 PLOT

The PLOT command allows the user to initialize the plot devices in ESL plotting library. Potting commands such as device number, metafile, and hardcopy unit, are present in this routine to eliminate the repetitious nature of the ESL plotting library for multi-device use.

### 3.2.1.8 \$ DCL COMMAND

The \$ DCL command allows the user to execute VAX/VMS DCL ( direct command language ) statements [4] without terminating the program session.

## 3.3 SPECIAL FUNCTION STATEMENTS

Some special functions statements have been included in the RSSE program to allow the user to manipulate the program in a easier fashion.

The first special statement is the "REDO" command. It allows the user to return to the top level of a nested entry loop. The nested entry loops always begin with the top entry command "ENTER IN THE NUMBER OF XXXXX". If REDO is entered in any of the following nested prompts, the user will return to the top entry command.

The second special statement command allows the user to execute a VAX/VMS COMMAND file [9], stop it, and then restart it again from an interactive terminal. The command file is stoped by the statement "QCOM", placed anywhere in the command file. The statement "GOCOM" enables the command file to resume at the prompt where the user enters the GOCOM statement.

### 3.4 NESTING OF MAJOR SUBROUTINES

RSSE						
CREATE	DISPLAY	EXPERIMENT	HELP	MAP	MENU	PLOTPACK
CKBASE	POLFIND	SUBSETS				
POLYPES		ARBITRARY				
DISPLAY		LOADIT				
POLFIND		SETGET				
ALLOCATION		ALLOCATE3				
MATRIX		ENTER_VALUES				
CALCP		LIST				
DB_READ		INDEXIS				
SCALE		CHKTHREE				
LINEAR		POL_DIVERSE				
DB_READ		AXIAL				
SCALE		LINEAR RATIOS				
POLFIND		AVAILABLE				
		ALLOCATE3				
		CONCAT				
		AXRAT_CAT				
		HHVV_RATIO				
		COMPLEX_SUM				
		IDENTIFY				
		ALLOCATE2				
		CLEAR_TABLE				
		NEAREST_NEIGHBOR				
		CORRUPT_TEST_SET				
		CORRUPT				
		AXL_RATIO				
		CORRUPT				
		HH_VV_VH_RATIOS				
		CORRUPT				
		SUM_COMPLEX				
		CORRUPT				
		DISTANCE				
		TABULATE				
		DISPLAY_RESULTS				
		INDEX_LIST				
		INDEXIS				
		POLFIND				
		NEW_POL				
		TABLE_PRINT				
		MISS_PERCENTAGE				
		TEXT_PRINT				
		INDEXIS				
		POLFIND				
		NEW_POL				

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